CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 1 of 11

101-03496/

ACKNOWLEDGEMENTS

The *Canadian Handbook on Health Impact Assessment Volume 2: Decision Making in Environmental Health Impact Assessment* was written under contract by Dr. Pierre Gosselin MD MPH and Pierre Chevalier PhD with contributions from Marcel Belanger MD, Daniel G. Bolduc Msc, Gaetan Carrier MD PhD, Daniel Gagne MSc, Marcel Gaucher MSc, Denis Gauvin MSc, Benoit Gingras MD, Benoit Girard MD, Isabelle Giroux MSc, Jacques Grondin MA, Andre Labelle MD, and Pierre Lajoie MD MIH.

The *Canadian Handbook on Health Impact Assessment Volumes 1, 2 and 3* are being prepared under the general guidance of the Federal/Provincial/Territorial Committee on Environmental and Occupational Health (CEOH). The CEOH has membership from all provinces, territories and the federal government. Membership on the CEOH represent environment, health and labour sectors.

Reviewers from within Health Canada include Dave Stieb of the Air Quality Health Effects Research Section, Kathy Hughes with the Priority Substances Section and Steve Wong of the Herbicide Toxicological Evaluation Section, all of whom provided comments on the Volume 2 material that pertained to their areas of expertise.

Health Canada's Office of Environmental Health Assessment (OEHA) is coordinating the production of the Handbook under the guidance of Roy Kwiatkowski, with the assistance of Sandra Owens.

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1.0 HANDBOOK PRESENTATION

1.1 Introduction

This second volume of the Canadian Health Impact Assessment Handbook is designed to create an integrated approach to developing a public health perspective within the framework of environmental assessments. More than a decade ago, the World Health Organization (Giroult, 1988) addressed the need to promote the importance and the benefits of integrating health into the environmental assessment process. Nation-wide consultations held in 1996 (Health Canada, 1996) clearly demonstrated that practitioners were interested in this subject. In particular, practitioners pointed out that while the case for the social component was well-known and developed, the relevant procedures, methods and indicators were less clear (Health Canada, 1997). They stressed the need to combine the efforts of the health sector and environmental assessment specialists, while also taking into account the views of the public. This Handbook has been developed to respond to these needs.

This second volume and the one that follows are practical extensions of the first volume, which presented the rationale for the necessary presence of the health sector in the area of environmental assessment, as well as a summary of current practices in Canada and in other countries. The present volume focuses on the procedures to follow when evaluating the implementation of a project or program in a given region. It also presents criteria for conducting an analysis, and provides detailed examples of impacts as a guideline for public health professionals.

The scope of the environmental assessments produced in Canada varies considerably, in accord with requirements of the provinces and the federal government. It would be impossible to cover the entire range of methodologies and disciplines that are available or useful, but the third volume of the Handbook provides a summary of the essential information on current approaches. The current volume deals with the types of projects and programs that are likely to require the expertise of local or regional public health authorities.

1.2 Target audience

The primary target audience will be health professionals who lack expertise in the area of environmental assessment (EA) but are occasionally asked to provide their views on issues such as the community health impacts of mining developments, landfill sites or high-voltage lines. Specifically, this could apply to doctors, nurses, sanitarians or environmental health inspectors who work in private practice, in community centres, or in local or regional public health services.

The Handbook may also be useful to other stakeholders who use or conduct environmental assessments, such as consulting firms in the fields of engineering and social science who conduct impact studies in Canada, as well as project proponents and the officials responsible for authorizing projects.

1.3 Contents of this volume

The following five sections focus on:

- the role of the health sector in EA (chapter 2);
- sustainable development as a framework for integrating risks and benefits to public health (chapter 3);
- an analysis of the data on health risks (chapter 4);
- the integration of a public health approach in developing public notices and public health interventions in EA (chapter 5);
- the development of a process for communicating with the public (chapter 6).

Readers should note that this volume was designed to allow for expansion in the future. More specifically, if the consultations which the Federal/Provincial/Territorial Committee on Environmental and Occupational Health is currently holding with various organizations are fruitful, the goal will be to develop a standard approach that would serve as a basis for the practice of public health professionals across the country. Several examples of the main environmental and health impacts of different types of projects are also presented in Appendix 1. If the consultations demonstrate the usefulness of developing summaries and grids for the main impacts of generic classes of projects, cooperation among the provinces, territories and federal government may lead to the development of summaries and grids for other economic sectors, building on the skills of the various stakeholders.

Although the approach used in Canada, including the regular and sometimes systematic involvement of public health officials in environmental assessment, is relatively new and inconsistently applied, it represents an exception when compared with other countries in the world (IAIA, 1996, 1997). Many countries, international organizations and universities have come to the conclusion that involving public health officials in the process will be necessary in the future, and are following the development of the Canadian Handbook with interest. Forseeably, our collective efforts and experience in this field will make a contribution on a far larger scale in years to come.

2.0 USEFUL CONCEPTS IN ENVIRONMENTAL ASSESSMENT

2.1 Introduction

This section will present a number of essential concepts in examining the function and role of health professionals in EA. Some of these concepts have been explored in greater detail in Volume 1, and will be dealt with briefly here. Others will be discussed more thoroughly. These concepts are:

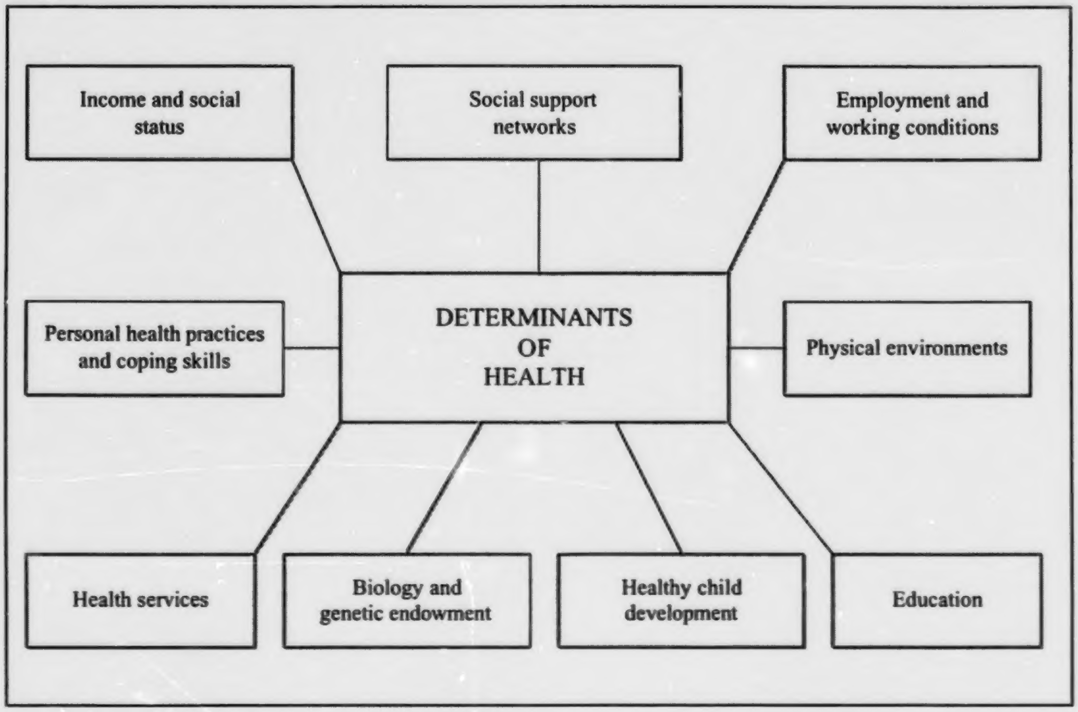
- the determinants of health (review);
- the various types of environmental assessments and their content;
- the normal sequence of events in the environmental assessment process (review);
- the role of health professionals in this process;
- suggested levels of involvement for health organizations in a variety of situations.

2.2 The determinants of health

Countless scientific studies have clearly stated that the health of individuals and populations is determined by a number of complex interacting factors.

Figure 2.1 summarizes the determinants of health (Health Canada, 1997).

Figure 2.1: Outlining the Determinants of Health


Income and social status
Social support networks
Employment and working conditions
Personal health practices and coping skills
DETERMINANTS OF HEALTH
Physical environments
Health services
Biology and genetic endowment
Healthy child development
Education

Some determinants have greater applicability for individuals, while others relate more particularly to the community and the forms of social organization. The health impact of these factors varies for individuals, regions and countries, and also depends on the virulence or toxicity of harmful exposures.

Although most of these concepts may appear self-evident to many health professionals trained in Canada, it is important to note that this is not necessarily the case in other parts of the world. Doctors and nurses who work in the public health field, for example, are familiar with the determinants of health and the broader concept of health promoted by the World Health Organization (WHO), which defines health as "a state of complete physical, mental and social well-being" (WHO), 1947).

However, they often overlook the fact that for many members of their profession, for professionals in other disciplines and for a large segment of the public, health remains, above all, the absence of illness or disease, with the latter often considered a misfortune which is unrelated to behaviour, or the result of poor access to health care services (Evans and Stoddard, 1994). In the context of EA, it is important to consider that these perceptions hold sway among proponents, public officials and the general population. Those seeking a more detailed discussion of these concepts are urged to consult Volume 1 of this Handbook (Health Canada, 1999).

2.3 Types of environmental assessments

Often, the terms *environmental assessment* and *environmental impact assessment* are used interchangeably. Some have maintained however, that environmental assessments have a broader scope. One recent study (Sadler, 1996) offered the following definitions:

- *Environmental assessment* is a systematic process which consists of evaluating and documenting the possibilities, capacities and functions of natural resources and systems, in order to facilitate sustainable development planning, and decision-making in general, as well as to manage the adverse impacts and effects of specific development proposals.

- *Environmental impact assessment* is a process that consists of defining, predicting, evaluating and attenuating the biophysical, social and other effects of development projects and physical activities, before important decisions and commitments are made.

- *Strategic environmental assessment* is a preliminary process for reviewing and evaluating policies, plans and programs, as well as other draft proposals for large-scale projects and initiatives.

The academic field of environmental assessment has spawned a number of sub-disciplines which are more conceptual than actual in nature, given that they are really components of EA. These include economic, fiscal, demographic, technological and social assessment (Vanclay and Bronstein, 1995). Many would also include political analysis in this category.

Volume 1 of this Handbook offered a descriptive definition of environmental assessment. This definition provides a good summary of the various components of EA and may be more useful for health professionals:

Environmental Assessment (EA)
A comprehensive and systematic process designed to identify, analyze and evaluate the environmental effects of a project in a public and participatory manner; environmental assessment involves the use of technical experts, research and analysis, issue identification, specification of information requirements, data gathering and interpretation, impact prediction, development of mitigation proposals, external consultations, and report preparation and review. In this Handbook, the term "environmental assessment" is used synonymously with "environmental impact assessment", "impact assessment", etc.

Two areas of focus are discernible:

- *Mezzosocial focus:* At this level, the main tools are local or regional environmental impact studies, which are conducted before projects are developed. Once in place, projects (factories, highways, etc.) are monitored for both environmental and health impacts. Environmental audits are also conducted to determine whether companies are managing their processes in a manner consistent with established standards such as ISO 14000 or the equivalent.

- *Macrosocial focus:* The principal tools at this level are strategic environmental assessments and product life-cycle studies which attempt to predict impacts on an entire ecosystem, ecozone, large administrative unit (such as a province or country), or continent. Follow-up activities take the form of reports on the state of the environment and the National Accounts as they pertain to natural resources (forests, water, etc.), as well as reports on health (mortality, morbidity, biological contamination, surveys on habits and perceptions). Reports on health sometimes focus on a specific risk factor or a particular sub-group within the general population, and examine the level of perceived or presumed risk. Exposure to organochlorines among Natives, or to heavy metals among pregnant women, are some examples of issues addressed through this traditional public health approach.

Table 2.1 Types of studies conducted in environmental assessment

STAGE	MEZZOSOCIAL FOCUS	MACROSOCIAL FOCUS
Prior to project development: *Prediction and investigation*	• Impact studies	• Strategic studies • Product life-cycle studies
During project development and after: *Monitoring and follow-up*	• Environmental and health follow-up (workers and neighbouring populations) • Audits (ISO 14000)	• Reports on the state of the environment • National Accounts - resources • Reports on health status

2.4 The role of health professionals

The role of health professionals varies according to the function they fulfill within their organizations, as well as on whether they become involved in local issues as private citizens. A number of demands are made of health professionals, and a variety of tasks are required to properly analyze a project or program submitted for review. These roles will be examined with respect to project justification, the type of environmental evaluation under review and the unfolding of projects over time. In conclusion, a few criteria for involvement by health agencies will be suggested.

2.4.1 Project justification

In examining or preparing an environmental assessment, it is crucial to determine whether the goal of the assessment is simply to control the adverse impacts that have been identified with respect to the project, or whether the assessment process will also attempt to decide whether the project is in fact justified and necessary. This latter option is included in a number of provincial processes (in Quebec for example). Ideally, this requires that a number of options, including project cancellation, be considered before the most appropriate one is selected. Typically, examining the justification for projects is not favoured among private proponents and governments. On the other hand, it is standard amone many citizens' groups, environmental groups and municipalities to question the justifications put forward for projects. This is particularly so when a development may bring the group no benefits and cause them inconvenience. Typical examples would be the installation of power lines in agricultural areas, or the development of a regional landfill site, which would have potentially adverse impacts on local residents.

Such substantive issues tend to remain unresolved, since those who oppose a project will always seek to question its soundness, regardless of whether such considerations are actually part of the process. Health professionals must be aware of this difficulty and take it into account, since their role does not consist of simply following a legal process, but entails protecting and promoting public health, regardless of whether or not a perceived risk is legitimate. In order to render their judgment on the acceptability of a project from a health perspective, they will need to concern themselves, at least minimally, with the justification for the project. We will return to this subject later.

2.4.2 Assessment content and the role of health professionals

The information contained in the various types of assessments and follow-ups is necessarily different. For example, health monitoring for workers in a factory can be very detailed and narrow in scope, and is sometimes conducted daily or on a continuing basis for some risk categories, such as exposure to chlorine. However, general population testing for the presence of heavy metals or organochlorines in mother's milk is not conducted on a frequent basis since temporal variations in these contaminants are slow to develop in a normal context.

Similarly, the role of health care providers varies according to the organization to which they belong and the training they have received (see Figure 2.1). It must be emphasized that all these various roles are complementary and essential, since the study of macrosocial aspects would not be possible without the input of clinicians from across the country. As well, practitioners count on large-scale studies in order to adapt their daily practice to emerging or newly-recognized risks.

Figure 2.2: Roles performed by health professionals in EA

	PREDICTION COMPONENT	KEY PLAYERS	MONITORING & FOLLOW-UP COMPONENT
POLICIES PROGRAMS PLANS	Strategic assessment	Clinical and research personnel in international organizations, government departments and university institutes: *Population surveillance; modelling; etiological research; knowledge synthesis*	Reports on health status
MANUFACTURED PRODUCTS	Product life-cycle analysis and technology assessment		Surveillance systems
PROJECTS	Impact studies	Local clinicians and regional public health practitioners: *Critical analysis and surveillance*	Various scientific publications
INDUSTRIAL AND OTHER PROCESSES		Doctors, nurses, occupational hygienists: *Surveillance and health program design*	Audits; environmental and health monitoring

The content of environmental assessment studies can vary considerably, depending on the subject matter, the type of study, the available data and the methodology employed.

The shortest studies are often those that deal with the most complex projects. The strategic environmental assessment conducted by the federal government in connection with the North American Free Trade Agreement (NAFTA) contained only 120 pages (Canada, 1992), although it dealt with a decision of the highest importance that would permanently alter natural resource consumption patterns and commercial exchanges across the continent. Under pressure from the United States, a parallel accord on the environment was added to NAFTA. At the time, however, no adequate data, provisional models or evaluation framework existed to permit an in-depth study. In addition, it is often difficult to foresee how thousands of companies and millions of consumers will conduct themselves, or exactly where impacts will be felt. These factors can render decision-making very difficult.

However, standard environmental impact studies, such as those conducted for large factories, mines and freeways, often contain as many as 1,000 pages, while studies examining even larger projects, such as northern mines and hydro-electric developments, may contain as many as five to ten thousand pages.

Many complex studies of this nature are read only by a few brave souls. Most stakeholders simply consult the sections that concern them. While the health component is normally allotted a single chapter in these studies, a more thorough reading of the impact study as a whole is necessary to understand and critically analyze this material. Clearly, in the majority of cases, environmental assessment requires a team effort involving both health professionals and specialists in a variety of environmental or technical areas that can have an impact on health. Health professionals need to consult broadly to understand and accurately assess the value of the more technical components of these studies.

2.4.3 Sequence of events and involvement of health professionals

Regardless of the type of environmental assessment being examined, there is one constant where health professionals are involved: they must perform their appropriate role and contribute their input to the process. Theirs is an important primary prevention activity, ultimately involving secondary prevention activities such as screening, follow-up, and various clinical functions. The environmental assessment process has been around for approximately thirty years in North America; a number of habitual responses have developed during this period. One frequent response is to underestimate public health considerations. Thus it is crucial that health professionals, as well as health agencies and institutions, play a significant and active role in the process.

Macrosocial focus

At this level (large ecosystem, province, country, continent), more often than not the task consists of examining the broad thrust of public policy (energy, transportation, agriculture, etc.) to ensure that public health concerns are included early in the process. Some countries, Canada among them, conduct strategic environmental assessments. Worldwide, however, practices tend to be more makeshift and informal (Thérivel and Partidario, 1996), and the public health component is often neglected. The same is often true at the provincial level, although efforts have been made in recent years, for example in British Columbia (Lewis, 1998) and in Quebec (CSEQ, 1998). These efforts include interdepartmental agreements that require a systematic examination (by representatives of the Ministry of Health among others) of policies, programs, regulations and guidelines that may have an impact on the environment (DHSS-MEF, 1987, 1992).

It is therefore necessary for public health officials, professional bodies (doctors, sanitarians, etc.) and other non-governmental organizations to get involved at the earliest stages of policy formulation. This can be accomplished by working with political parties, government departments, interdepartmental committees and parliamentary commissions, and by participating in public consultations and other mechanisms designed to give voice to concerns. Institutional settings may vary from one jurisdiction to the next, depending on the administrative structures in place.

Still, formal analysis of the public health effects of the environmental impacts of government policies, plans, and programs, is a science that has yet to be explored, and a relatively undeveloped discipline. As a result, policy statements and ideological declarations are encountered more frequently than substantive analysis. However, some organizations have begun to address this need by undertaking often detailed assessments of draft legislation and regulations to determine their impact on public health. For example, strategic assessments focussing on issues of health were recently conducted on new anti-tobacco legislation (DHSS, 1998), as well as on regulatory proposals regarding the quality of drinking water (MEF, 1992).

The scope of strategic environmental assessments is broad and can include an examination of the following elements (Buckley, 1998; Goodland, 1998; Thérivel, 1996) in terms of their environmental and health impacts:

- public policy, including administrative policies (such as privatization and budget cuts);
- budgets and taxation;
- international and national treaties;
- significant pollutants (e.g. dioxins and mercury);
- geographic region (e.g. the Arctic, rivers);
- temporal trends (e.g. urbanization, agricultural land use);
- technology (e.g. biotechnology in food production);
- economic sectors (e.g. impact of the automobile);
- generic project categories (e.g. cogeneration of electricity using gas).

Although environmental assessments in Canada already focus on a number of these elements, this practice is neither systematic nor automatic. However, the current trend is to include this type of analysis, which is an essential part of developing policies that are consistent with the principles of sustainable development. In the absence of such analysis, governments often end up adopting policies that run counter to these principles. Project assessment cannot compensate for an initial concept that is unsound.

Mezzosocial focus

At the local or regional level, the role of health professionals is more clearly defined, since legal and administrative processes are more firmly established, and the stages of project development more clearly circumscribed. These stages may vary from one province to the next, but usually adhere to the following five-step model, which was described in Volume 1 of this Handbook:

- *Project description:* Describe the project and determine whether or not an EA is required;
- *Scoping:* Scope or identify the key issues to be considered in an EA;
- *Determining public participation significance:* Assess the potential effects and determine their significance;
- *Mitigation and follow-up:* Identify mitigation measures to prevent, minimize or compensate for the impacts and monitor the project once it is in operation;
- *Recommendations:* Make recommendations on the fate of the project and conditions attached to its approval.

Health professionals can play a useful role at every stage of the process. In the preliminary stages, this role involves determining the content of the guidelines for preparing an impact study. While these guidelines have tended to be specific to individual projects, the current trend is towards generic guidelines for entire classes of projects (MEF, 1997-98), including a health component developed in consultation with public health authorities. An example of this type of generic guideline is provided on the next page (MEF, 1998). In some Australian states, such as Tasmania (PEHB, 1997), a separate process is favoured for health component guidelines, but these remain generic guidelines that can be applied to all projects.

Box 2.1 **Sample generic guidelines for describing the impacts of a hydro-electric power line**

- disturbances to the aquatic environment caused by water crossings: effects on water levels, discharge and ice regime; effects on riparian vegetation and fauna (fish and waterfowl), etc.
- impact of the development on the quality of soil, surface water and ground water (drinking water in particular).
- effects on faunal populations and their habitats, with a particular attention to threatened or vulnerable species or species likely to be designated as such, and to the habitats of such species (surface area affected, number of species affected, population density, etc.).
- effects on vegetation, in particular plant species that are threatened, vulnerable or likely to be designated as such.
- impact on current and anticipated land use, in particular the effect on recreational uses of creating new access to the area, including such uses as vacation homes, hunting and fishing.
- anticipated effects on the area's agricultural potential, loss of acreage and economic value of the land, effect on access to the land and on the movement of farm machinery, changes in agricultural drainage, consequences for farm animals.
- anticipated effects on the area's forestry potential, loss of acreage and economic value of the land, significance of these losses for the forestry activity in the region.
- impact on existing or projected public infrastructures, such as roads, electrical power lines and stations, water intake, parks and other natural sites, bicycle paths and other recreational amenities, hospitals, schools, etc.
- effects on lot sizes and building set-backs, including changes in building access, destruction of existing land subdivisions, fragmentation of land holdings and expropriations.
- changes in levels of exposure to electromagnetic fields for residents in the vicinity of the proposed line.
- biological effects of electromagnetic fields on public health, including an overview of current national and international research on this topic.
- economic impacts of the project, including job creation, the attraction of energy-intensive industries to the region, and effects on land and property values, local government revenues, etc.
- disadvantages linked to the construction phase (disruptions in the transportation network, noise, dust, etc.).
- repercussions linked to vegetation control on rights-of-way, including potential impacts on public health.

Source: MEF (1998)

This type of generic approach requires sufficient familiarity with the practice of environmental assessment, as well as a fairly high volume of activity. Otherwise, project-specific guidelines remain preferable. Samples of project-specific guidelines are available from the Canadian Environmental Assessment Agency (CEAA, 1998) or from provincial Environment Ministries. The major difference between these two approaches lies in the discretion (and responsibility) given to proponents under the generic approach. Proponents are required to: identify significant impacts; determine health problems requiring study; select methodologies; determine which multi-criteria analyses are to be conducted, etc. They must also justify their choices. The generic approach demands a high level of expertise, and automatically requires that promoters conduct broad consultations to ensure that their impact studies will withstand scrutiny. Among other things, project-specific guidelines state which chemical products are to be examined, the species that will be considered and the tests and methodologies that will be used. Therefore, the onus is on the proponent to adhere faithfully to the requirements. This approach often generates an abundant literature of questionable usefulness examining insignificant impacts. Box 2.2 on the following page provides a sample of project-specific guidelines.

Box 2.2 Project-specific guidelines: Sample

Impact prediction should be as factual an exercise as possible. It should demonstrate the nature, magnitude (quantitative aspect), scope (spatial aspect), duration (temporal aspect), risks and uncertainty factors of any change to significant elements of the environment. Impact predictions will be general in nature, given the fact that the location and size of the areas to be sprayed with pesticides have not yet been established.

The initiator must first develop predictions with respect to impacts on human health, using the toxicological risk analysis technique. Particular attention should be paid to workers involved in spraying, as well as to the populations that live in nearby areas, including Native populations.

Risks to be considered include any new risk of cancer, as well as other effects that are harmful to health, including immunosuppressive effects, and potential effects on reproduction and development. The risk analysis must begin by identifying toxic pesticides that may pose a significant risk to public health. For these substances, analysis includes a detailed examination of potential exposure for individuals residing in or near the spray area. Exposure analysis should consider all potential pathways of exposure, with particular attention to inhaled substances and the consumption of locally grown fruits and vegetables (wild fruit and local vegetable gardens). A detailed description of all the models used to simulate the transfer or fate of pesticides in the environment must be provided, along with the values of the variables used for modelling purposes. The initiator must also provide a brief overview of the toxicological and epidemiological studies performed on the substances under review, and indicate the basis established to estimate risks (reference doses or quantitative methods employed to assess any new risk of cancer).

Impact predictions must also encompass organisms that are not targeted, including mammals, birds, fish, amphibians, land and aquatic micro-organisms and, more particularly, pollinizers and vegetation.

The proponent must pay particular attention to bird populations and provide a summary of the work dealing with direct and indirect effects (such as efforts to capture insect-eating birds).

Predictions concerning impacts on water, air and soil must also be provided.

Finally, particular attention should be paid to cumulative impacts.

An analysis of the methodological soundness of impact studies, including conclusions and recommendations, is a cornerstone in developing local action to prevent or mitigate health impacts. Once again, a team effort is required to monitor the start-up of projects and their subsequent operation. This analysis and monitoring is described in greater detail in the following sections.

2.4.4 Criteria for the involvement of health agencies

Introduction

The degree of involvement of health agencies and professional associations in EA is clearly dependent on available resources and on the interest (in the broadest sense) which a given project or policy generates.

In Quebec for example, the regional public health branches (directions régionales de santé publique or DRSP) were invited to submit their views on a number of projects (mines, factories, pesticide spraying in forests) in the early 1980s, at the request of citizens groups and public agencies. After a period of wavering, during which some DRSPs seemed hesitant about providing their views on projects, it has become common practice since 1990 for the branches to conduct in-depth analyses on all projects submitted to the environmental assessment process, and to issue public notices. Key factors in bringing about this change include: the expectations of the public and of government departments and organizations involved in EA; resource sharing among regions, including providing expertise to areas where this is lacking; and the development of a common procedure for conducting assessments (CSE, 1993).

Despite these efforts, the study of the health component remains a neglected aspect of the EA process (Davis, 1997). It is estimated that as many as 90 to 95% of all environmental assessments conducted in the world are deficient in the areas of health and safety (Sloff, 1995).

At the ministerial level, the involvement of public health agencies can take a very different form. Indeed, the regional role largely consists of critically analyzing projects, contributing to and taking part in public consultations, and performing monitoring and follow-up activities that normally fall to local or regional public health agencies. In the case of strategic assessments, however, the general expectation is that the Minister of Health will take charge of conducting and funding the necessary research. Given that the questions involved are often complex and difficult to address, this can be an arduous task, difficult to integrate into current programming.

Two examples of the types of issues confronting central agency managers (EEA, 1995) are provided below:

- a comparison of various scenarios for managing household waste, including their respective impacts on health;

- the justification, environmental impacts and health impacts of agricultural subsidies.

Similar issues arise in many sectors which consume large amounts of energy and resources, such as industry, energy, transportation, forestry and tourism.

Criteria

The following criteria can be used to assist organizations in determining the scope of the effort that is required. These criteria can also help organizations and institutions acting as project or program proponents to make way for more substantial involvement by the health sector, in preparing and analyzing an environmental assessment study.

At the ministerial level

All program, plan, and policy initiatives in economic sectors with a major impact on the environment should involve health authorities at an early stage. Agreements to this effect already exist in several Canadian provinces, and are part of the federal environmental assessment process. The sectors most likely to interest the health sector include:

- land-use management and urban planning;

- industries (including mining);

- energy generation and transmission;

- road, rail and air transportation;

- agriculture and fisheries;

- forestry;

- tourism and recreation;

- waste management.

Since health care services have grown to represent approximately 10% of GDP, and produce their own waste and other impacts, it would be appropriate for them to address their own contribution. Therefore, it is important to add:

- health care and health care services.

Aside from the impacts already identified, other criteria include technological innovations, which are best examined in depth prior to implementation, and public interest. The latter is something to which all *public* health agencies must remain responsive. Of course, the anticipated scale of any initiative remains a determining factor.

Public health authorities must also examine a number of other aspects (PEHB 1997), including:

- the likelihood of large-scale demographic or geographic changes within the community, including impacts on infrastructure;
- the likelihood of human exposure to physical, chemical or biological contaminants;
- the likelihood of impacts on vulnerable groups (for example children, the elderly, the chronically ill);
- the likelihood of impacts on disease vectors in the environment or on recreational resources;
- the likelihood of impacts on the food chain, including agricultural land;
- the likelihood of impacts on liability risks.

Increasingly important are concerns about what is commonly known as "global change". This includes climate change, ozone depletion, and ecosystem change, and their admitted or perceived role in increasing liability risks, as well as new infectious diseases, the geographic spread of tropical disease carriers and toxic algae.

Table 2.2 Suggested degree of involvement for central public health agencies

	Small-scale initiatives	Large-scale initiatives	Large-scale initiatives involving technological innovations or strong public interest
Economic sectors which have a major impact on the environment	average	significant	very significant
Economic sectors which have a more moderate impact on the environment	low	average	significant

Frequently, there is a sharp increase in the number of small-scale projects within a given region, province or country. In recent years, for example, we have seen a significant increase in the number of hog farms in several regions of Canada. When considered on its own, a hog farm may appear to have a relatively low impact on the environment or on human health. However, when there are fifty such projects within a given watershed, the impact can be very great. Similar issues arise with the proliferation of thermal power stations and small-scale hydro-electric dams. Sound analysis requires situating the project within a broader context.

At the local or regional level

The criteria outlined at the ministerial level also apply at this level. Added to these are criteria that are more concerned with the scale of a project (expressed in monetary terms) in relation to the size of the host community. Parameters to determine the appropriate degree of involvement for public health authorities and their partners are suggested in Table 2.4:

Table 2.4 Suggested degree of involvement for regional and local public health agencies

Type of community	Small-scale projects < 1 $M	Medium-scale projects 1 to 10 $M	Large projects 10 $M to 1 $B	Very large projects > 1 $B
small/isolated	low	significant	very significant	very significant
small < 10k inhabitants	low	average	significant	very significant
average 10k to 100k inhabitants	low	low	significant to very significant	very significant
large > 100k or very large > 1M inhabitants	low	low	average to significant	significant to very significant

The sectors that are deemed to have a high impact on the environment are the same at this level.

There are many ways to determine an appropriate level of involvement by public health authorities. As a guide for determining the kinds of efforts that are frequently required in documenting the public health component of EA, a few parameters are proposed below:

- *Low level of involvement:* Use of guides and simple literature reviews; determination of compliance with standards in force; informal consultations by key communicators; succinct written notices.
- *Average level of involvement:* The preceding items, as well as informal consultations with specialists and key communicators; determination of compliance with the strictest standards in force in the world; brief written notices.
- *Significant level of involvement:* Exhaustive reviews of pertinent literature; formal consultations with specialists; formal public consultations; risk analyses; reports and briefs; dissemination through the usual channels.
- *Very significant level of involvement:* The preceding items, as well as surveys, epidemiological studies, psychosocial studies; reports and briefs; major dissemination initiatives.

The last two levels of involvement are most often the domain of larger teams normally found within government departments, institutes or universities. However, interventions at these levels are sometimes managed by regional organizations, if adequate specialist support can be provided. Indeed, large projects are often undertaken in more peripheral regions. It is still essential to actively involve regional public health agencies and health professionals charged with managing the future implementation of a project.

3.0 SUSTAINABLE DEVELOPMENT AND HEALTH: FRAMEWORK FOR INTEGRATING PUBLIC HEALTH INTO ENVIRONMENTAL ASSESSMENT

3.1 Introduction

The preceding sections have examined the critical role health professionals can play in environmental assessment. To adequately fulfill this role, and to base their views on reliable criteria, health professionals need a shared world view, one which includes values connected with health protection, risk and disease prevention, and the promotion of behaviours that sustain health. This vision must also encompass other aspects, including economic development, as well as environment and ecosystem protection. This is the approach behind the concept of sustainable development, which is now part of many federal and provincial laws, as well as international treaties. Even the very conservative Organization for Economic Cooperation and Development is now using this concept to chart its future course (OECD, 1997).

3.2 Definitions

The definition of sustainable development has been the subject of much debate, which has been joined by many excellent publications. The human health component is neglected in some publications (for example CCME, 1993) and highlighted in others (Health Canada, 1997), according to the respective mandates of each. In conducting environmental assessments, it is desirable to identify the health component as a key element of sustainable development, on a par with economic and environmental components (Figure 3.1) This approach does justice to the interdependence of various determinants of healthy and equitable development.

Figure 3.1: Health in the context of sustainable development

Activities having a natural origin				Natural response
	Equity	Economy	Sustainability	
		HEALTH		
	Social system		Environment	
Human activities		Viability		Human response

Source: Gosselin (1991)

Whereas health professionals generally include the social component in their definition of health, in EA the practice is different: health is often considered a facet of the social component, particularly in matters not related to toxicology or technological risk (these normally fall into the environmental component). Given that the approach favoured has more to do with past training than any other factor, these classifications are of little importance; it is sufficient to know that they exist.

What *is* important is to understand the goals of sustainable development and to derive operational principles that may be useful in developing public health input. In this connection, the line of thought suggested by Robert Goodland and Herman Daly (1995) presents many important similarities with the official policy of governments across Canada in matters of health, the environment and the economy (see Appendix 1). The challenge that remains is to put the goals outlined in Figure 3.2 into practice in our daily decision-making.

Figure 3.2: Objectives of sociosanitary, economic, and environmental sustainability

SOCIOSANITARY OBJECTIVES
Empowerment
Participation
Equity
Poverty alleviation
Social cohesion
Population stability and Health
Institutional development

ECONOMIC OBJECTIVES
Development for all countries
Growth for LDCs
Efficiency
Poverty alleviation
Equity

ENVIRONMENTAL OBJECTIVES
Ecosystem integrity
Conserve carrying capacity
Climatic stability
Conserve biodiversity

As Grø Harlem Bruntland suggested in the report which originally put forward the concept of sustainable development (WCED, 1987), the focus of all sustainable development is ultimately human health, which is dependent on social, economic and environmental sustainability. Clearly, this is a very ambitious objective, but it can also be useful in developing a clearer vision of the goals we must achieve to ensure that social development is consistent with the promotion and protection of public health.

3.3 Significance of the three realms of sustainable development

For those who may not be familiar with the scientific studies that led to the concept of sustainable development, a number of references to background information are provided in the bibliography at the end of this Handbook. Here we will examine a few basic concepts (ecosystem, economy and social system) which may be of assistance to the reader.

3.3.1 Ecosystem

The most significant trend observed throughout the 20th century has been typified by a demographic explosion and the marked deterioration of many ecosystems around the world. The Earth's population has undergone a five-fold increase in less than a century, and the demand for fresh water, arable land, energy, wood, fish, and other resources has often outstripped the capacity of ecosystems to regenerate themselves. This view is shared by every organization in the UN and thousands of scientists around the world, who have come to realize that human beings are taking up more and more space, harming other species and interfering with the ability of air, soil and water to renew themselves (Keating at al, 1997). In addition, the unintended pollution caused by a number of technological innovations such as PCBs and the automobile have only made matters worse.

It is also important to note that many services that we derive from our ecosystems, such as water and air purification, waste recycling and food production, are never recognized in our national accounts, whose best known statistic is the gross domestic product or GDP. In our current economic system, the fact that a dollar value is not attached to ecosystems often means that managers give these considerations little or no attention. This persists despite the fact that ecosystems provide irreplaceable services, such as ground water and the atmosphere itself.

Table 3.1: Classification of services provided by ecosystems (after Costanza et al., 1997)

1. Gas regulation
2. Climate regulation
3. Disturbance regulation
4. Water regulation
5. Water supply
6. Erosion control and sediment retention
7. Soil formation
8. Nutrient cycling
9. Waste treatment
10. Pollination
11. Biological control
12. Refugia
13. Food reproduction
14. Raw materials
15. Genetic resources
16. Recreation
17. Cultural

The authors of one recent study (Costanza et al., 1997) attempted to assess the monetary value of the services provided by ecosystems in different biomes (water, land, etc.). Their estimate, which they have termed conservative, is US$33 trillion per year. By comparison, the gross domestic product of the entire planet is approximately US$18 trillion per year. Most of these ecological services are indispensable to life on Earth and many form the basis of our economic activities. Yet they are rarely considered in cost-benefit analyses, and seldom integrated into the decision-making process. There are many reasons to rigorously protect our life-sustaining ecosystems, including human life itself, our economic activities, and the fact that ecosystems are irreplaceable.

3.3.2 Economy

There are now hundreds of studies attesting to the effects of adequate or deficient incomes on health. This variable is so significant that epidemiological studies control for it in an attempt to isolate its effects from other less important causal factors.

A number of international publications have demonstrated the link between low incomes and poor health in developing countries (for example UNDP, 1997), but these disparities exist in Canada as well (CPHA, 1997). Some of these studies show disparities in life expectancy, on the order of 10 years, between the residents of affluent and poor neighbourhoods within the same city. The relationship is sometimes indirect, as in the case of behaviours that are harmful to health; but it can also be direct, as with the permanent stress induced by financial insecurity (see Evans et al., 1994). This effect would appear to be cumulative, with a dose-response curve (Lynch, 1997).

In general, an average income is sufficient to ensure good health, beyond minimum subsistence. The experience of many countries shows that investments in primary health care (vaccination, care for pregnant women), in education and environmental health (drinking water, waste management, air quality) are crucial factors in the relationship between economics and health. Clearly, an adequate income for individuals does not suffice: sound government decision-making is required, particularly regarding investments in pollution control, preventing environmental degradation and promoting the benefits derived from our ecosystems.

3.3.3 Social system

The economic system and the social system are closely linked and interdependent. Direct and indirect links can also demonstrated between health and the social system.

Even in Canada, health professionals sometimes need to be reminded that after genetics and age, the social environment is probably the most important determinant of health (Evans et al., p.74). The relationships that evolve among individuals or groups of individuals influence their state of health. These relationships can encompass the ways in which work is organized, criminality, power structures, culture, dietary influences, and other factors. Some would also include equitable income distribution within the social sphere. Individuals' sense that they can control their own lives also appears to be highly important, as is the ability to rely on family or a social support network in case of need. Significant discrepancies in mortality and morbidity can be observed in situations where individuals feel they have little control over their professional lives. The studies conducted by Marmot (1998) with British civil servants showed age-specific mortality rates that were three times higher among lower-level employees when compared to rates for upper management. In studies performed by Wilkinson (1989, 1992) death rates adjusted over time, as well as comparative rates between countries, show similar discrepancies relating to the distribution of material resources within populations. In the third volume, an entire chapter is devoted to this subject.

These discrepancies in the area of health can be significantly reduced if governments are prepared to invest wisely in such areas as education, primary care and environmental management (Caldwell, 1986). This can be observed by contrasting the experiences of nations of comparable economic standing but markedly different sanitary conditions. Equitable income distribution among individuals is also a key variable influencing the health of the population. It has been observed that countries in which wealth is distributed more equitably achieve a higher level of population health than other nations of comparable affluence. Increased social stress can also bring about a significant deterioration in the health of a population, as the recent experience in Russia eloquently demonstrates (Leon, 1997). In 1994, a Russian male had only a 50% chance of living beyond the age of 60, as compared to a 90% chance among Canadian males. Tobacco and alcohol consumption, poor nutrition, significant social and economic instability, depression and deteriorating health care have all been identified as causal factors in this new situation (Notzon, 1998). Between 1990 and 1995, the life expectancy for Russian men decreased by approximately seven years.

3.4 Sustainable development as a daily focus

It would appear that those in charge of making political and economic decisions have an inadequate understanding of the issues that have been raised here. As a result, information dissemination is another task faced by health professionals in preparing public health notices in connection with EA.

Adopting the sustainable development framework as a criterion in preparing public health notices in EA means that health agencies must provide their views on:

- the likelihood that contaminants or anticipated hazards may have an impact on health and quality of life and, ultimately, health agencies' views on desirable levels;

- the foreseeable equity in the distribution of risks, disadvantages and benefits, and, ultimately, health agencies' views as to what would constitute a desirable distribution;

- the impact of the initiative being considered on the preservation of life-sustaining ecosystems and on the services derived from these ecosystems, and, ultimately, health agencies' views on desirable impact mitigation measures.

Most initiatives, projects, programs and policies contain both positive and negative elements; from a public health perspective, it is important that these be brought into balance. Still, many useful actions which can move society toward sustainable development require a social consensus, which develops gradually and often slowly. Therefore, it can be useful to propose concrete compensatory or mitigation measures for specific projects. Such actions can include planting a forest or creating wetlands to compensate for losses brought about by new construction projects, or setting up a social development trust fund for a community coping with the residual inconvenience caused by a new factory.

For public health agencies, opposing the development of a project by invoking sustainable development principles can sometimes be delicate. On the other hand, it is entirely appropriate to give greater weight to this criterion when developing government policies and programs, or when planning mega-projects (or a series of projects) which can have a major impact on the course of a society. Energy supply policies, subsidies favouring the automobile, and hydro-electric developments in virgin wilderness are examples of high impact initiatives which must now undergo the test of sustainability.

The concept of sustainability implies the existence of a limit to resource use. Limits are accepted when it comes to elevators or bridges; parking lots have a limited number of spaces and common sense should tell us that a lake contains a finite number of fish. However, many people are not prepared to admit that such limits should apply to our use of natural resources (Carins, 1997). Economist Kenneth Boulding (1966) summed up this position rather well more than 20 years ago:

> Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist.

It bears repeating that project-related public health notices mainly deal with the effects of contaminants on health and quality of life, and on the fair distribution of risks and benefits. The ecosystem integrity component applies most often in the case of strategic assessments, or when a mega-project (or a series of projects) is being proposed. With smaller projects, the focus is on preserving the recreational or cultural uses of ecosystems, although it is generally recognized that avoiding all forms of inconvenience may be difficult at times. In such cases, it becomes important to adequately replace ecosystem loss, either in the immediate vicinity or elsewhere in the region.

3.5 Developing concrete sustainable development objectives

Box 3.1 offers concrete sustainable development principles, in a variety of categories, as guidelines for developing policy or implementing major projects (Écosommet, 1995). These principles were developed during broad multiparty consultations held in Quebec from 1994 to 1996 with a view to developing sustainable projects, and are inspired by the major orientations of Agenda 21 (Keating, 1993), WHO (1992), and a number of Canadian publications that deal with this topic (including CCME, 1993; NRTEE, 1993, 1994). The proposed principles can ultimately serve as criteria for examining projects and policies and developing useful initiatives to promote sustainable development.

Box 3.1: Specific sustainable development principles

Biophysical environment

Natural resources (including energy resources): One of the goals of sustainable development is to ensure that these natural resources are managed rationally, and that access to renewable and non-renewable resources is equitable. The basic principles are the following:

- never exceed the regeneration rate of renewable natural resources;
- never exploit non-renewable resources at a rate or at a price that will necessitate their eventual replacement by renewable resources;
- improve knowledge and monitoring of natural resources;
- promote the conservation of natural resources by reducing the pressure on these resources (over-consumption, air, water and soil pollution), especially in areas that hold a particular attraction.

Biodiversity and habitats: Sustainable development seeks to maintain ecosystem integrity through an integrated management approach. The basic principles are the following:

- minimize the loss of genetic, species and ecosystem diversity;
- ensure landscape and habitat conservation, including both our natural and architectural heritage;
- clean up and restore habitats that have been altered or destroyed;
- limit or prohibit human activities that can translate into adverse impacts on natural species and architectural heritage;
- develop human activity in harmony with the natural environment.

Human environment

Health: Sustainable development also implies taking action to promote and protect health and prevent disease. The basic principles are the following:

- reduce gaseous, liquid and solid emissions, in order to minimize risks to public health through the contamination of food, water, air or soil;
- develop and improve emergency plans to deal with environmental accidents, as well as measures to monitor the environment, especially exposure to substances that are harmful to human health;
- in the workplace, replace hazardous technologies and materials with alternative products and technologies that are less harmful;
- create conditions that promote healthy lifestyle habits (physical exercise, good nutrition, anti-tobacco measures, etc.).

Quality of life: Improving quality of life is an important aspect of sustainable development. The basic principles are the following:

- reduce or eliminate irritants (noise, unpleasant odours, visual degradation of the landscape) which affect quality of life for human populations, both in rural and urban areas;
- promote the revitalization of urban and rural environments;
- make nature and culture accessible to the public through leisure and community-based activities;
- develop a social and physical environment that favours the dissemination of information and involves citizens of all ages in community management.

Economy and employment: The concept of sustainable development implies that actions taken must be economically viable and fair for affected populations, particularly in the case of regional development. The basic principles are the following:

- create employment, particularly for young people living in communities and areas dealing with high levels of unemployment and social assistance;
- improve and maintain quality of life within the framework of existing employment;
- internalize the costs and benefits of external project effects (pollution for example), including the public health protection aspect;
- improve the level of education and training of individuals to enable them to play an active role in society.

Stakeholders

Achieving sustainable development goals requires a concerted effort on the part of all stakeholders, including private citizens, corporations, public and private organizations, and government.

Citizens: Development cannot occur in a sustainable manner without the active involvement of citizens. The basic principles are the following:

- develop measures to encourage the population to modify its attitudes, habits and behaviour, with a view to reducing over-consumption of water, energy, natural resources and chemical products, and reducing the production of waste that is harmful to the environment;
- intensify measures designed to promote reduction, reuse and recycling and the reclamation of primary and secondary resources;
- support concrete cooperative actions designed to promote the accountability of citizens and citizens' groups, and to encourage them to address their own individual impact on the environment;
- aim for a fair balance in the distribution of benefits and disadvantages connected with development.

Corporations and public and private organizations: The involvement of employers, companies, workers and public and private organizations is essential and provides the ability to intervene on a variety of levels. The basic principles are the following:

- reduce and monitor air, water and soil pollution;
- limit the production of goods and services that are harmful to ecosystems and human society;
- promote the quality and sustainability aspects of goods and services;
- ensure that pollution and waste do not exceed the environment's ability to absorb them;
- implement measures to reduce, reuse, recycle and develop primary and secondary resources;
- develop technological innovations that increase production efficiency by reducing the use of natural resources, energy and water;
- develop and utilize new technologies that offer better performance from an environmental standpoint.

Governments: The various levels of government are key players in the promotion of sustainable development. The basic principles are the following:

- promote education and awareness among all social groups (public, NGOs, universities and industry) with respect to the importance of sustainable development;
- foresee and prevent problems instead of attempting to solve them once they have

- improve and adapt policies, legislation, and existing financial and fiscal measures, with a view to promoting activities that protect and improve ecosystems, and discouraging actions that are harmful (over-consumption of natural resources, disposal of solid or dangerous waste, greenhouse effect, acid rain and ozone depletion);
- organize information (assessment tools, data regarding indicators) to make it more accessible (reliable, available and factual).

4.0 ANALYZING HEALTH RISK DATA

4.1 *Introduction*

It is normally easy to obtain data on the benefits of a given project, program or policy because proponents usually give this aspect considerable prominence. The quality of the data provided with respect to the advantages and benefits of a project can vary, and merits at least a cursory assessment. This aspect is discussed in greater detail in Chapter 5 of this volume and in Volume 3 (see sections dealing with the economy and social impact assessment).

Assessing data that deals with the risks of a project can be a more difficult exercise. The public generally expects that the responsible public health agency will examine this issue in depth and that, in the final analysis, risks will be negligible. For their part, proponents tend to expect a review that will recommend an acceptable or reasonable degree of risk. Definitions of these terms tend to be somewhat ambiguous, given that the people who bear the burden of risk are often not the people who derive the benefits. The issue of risk management and the concept of acceptable risk are discussed in Chapter 5.

4.2 *Common problems in conducting an analysis*

A brief overview of problems frequently encountered in preparing or analyzing an environmental assessment is provided below.

4.2.1 Spatial and temporal scale

It is often difficult to identify a single analytical scale for the assessment of health impacts. On a spatial scale, the zone of influence varies based on the nature of exposure to a risk factor. For example, the zone affected by the effluent produced by a smokestack is different than the area affected by noise; as well, economic spinoffs can "travel". On a temporal scale, toxicity can be variously described as acute, chronic or transgenerational. Therefore, it is important to specify desirable spatial and temporal scales for every significant risk.

4.2.2 Risk groups

Similarly, the types of groups that are judged to be at risk will vary based on the type of problem being addressed. Generally speaking, we know that certain individuals are susceptible to greater exposure to contaminants due to:

- physiology (e.g. newborns, children, pregnant or breastfeeding women, the elderly);
- illness (e.g. the immunocompromised and those suffering from respiratory conditions or allergies);
- lifestyle (e.g. Natives who consume large amounts of game meat, smokers);
- behaviour (e.g. children's habit of putting objects in their mouths);
- insecure living conditions (e.g. among immigrants).

It is also important to specify, for each significant risk factor, which populations warrant study. Some social groups are more likely than others to see their quality of life being affected by a project, due to such factors as: the distribution of available employment; the training required for such employment; the internal management practices of the newly installed company; and the distribution of impacts from a land-use perspective.

4.2.3 Workers

Generally, workers are the group most exposed to contaminants. Still, within the framework of an environmental impact study, it is difficult to predict exposures and determine the concrete measures that need to be taken, however desirable that might be.

For example, it is practically impossible to adequately simulate contaminant emissions for an industrial process before engineering details have been worked out, which normally occurs after a proponent has been authorized to proceed with the project. Consequently, it is preferable to place the emphasis on workplace health and safety programs that make use of the best practices available for environmental monitoring and health surveillance. This applies at all stages of a project, although the stages presenting the greatest risk are construction and the "breaking-in" phase.

The relationship which develops between new workers and local communities can also assume considerable importance in some situations. A typical example is the development of large sites in isolated regions. This relationship can have a positive or adverse impact on the health of individuals and communities.

4.2.4 New technology

Frequently, projects submitted for EA include a new technology component. When information on the new technology is lacking, this can further complicate the process. The following principles may assist in evaluating the potential performance of new technologies:

- In most industrial processes, there is a financial incentive to use the least amount of natural resources possible (water, wood, energy, etc.) when such resources are sold at market price. As a result, the efficiency of new technology can be compared with that of the technology being replaced by examining resource consumption per unit of production. Greater efficiency implies less waste, although total production volumes also need to be taken into account.

- The experience and seriousness of proponents and their consultants need to be assessed, based on similar projects developed in the past.

- Proposals put forward by proponents with respect to the surveillance of technology and the monitoring and control of emissions must be rigorous and completely transparent.

4.2.5 Relevance of existing health data

Making use of existing health data in environmental assessment raises a number of important methodological problems (Davies, 1997):

- Health information is usually collected for specific purposes and can be difficult to modify or adapt for use in EA. For example, most medical data are difficult to use in EA because information is collected for physician billing, insurance and health care planning, or health care utilization studies. As a result, the accuracy of diagnoses varies considerably.

- Although most countries collect national health statistics, there is often a shortage of information on health status and the determinants of health for specific communities and for individuals. In particular, there is a shortage of information on morbidity, psychological well-being and socio-economic factors.

- Health information is rarely examined in relation to environmental quality. Although the biophysical environment is a recognized determinant of health, the study of precisely how the environment affects health is still in its infancy. More particularly, causal relationships remain difficult to establish with respect to individuals.

4.2.6 Methodology

A variety of methodologies can be useful in assessing health impacts. Table 4.1 succinctly presents the principle methods used in environmental assessment, and a number of methodologies are discussed in the third volume of this Handbook. It is important to remember that every methodology offers both benefits and disadvantages (see Davies, 1997, Table 3), which means that a considerable amount of professional judgement is required in selecting an appropriate approach. Such considerations as cost and the expertise available within a given team must also be taken into account. For example, geographic information systems (GIS) still require a considerable investment and in no way represent a panacea. Experienced EA practitioners like Canter (1998) have stressed that the simplest methods in terms of data, personnel and technology requirements are also those that prove the most enduring. Such methods include the study of analogs and the use of checklists, expert opinion and matrices.

It is important to develop a coherent approach and to provide reports of great transparency that specify limits. Ultimately, it is always preferable to consult a few experts or citizens' groups by phone than to take no action; such consultations represent an effective and low-cost methodology.

In the next chapter, we will examine a number of risks frequently encountered with different types of projects.

Table 4.1: Brief description of 22 types of methods in EIA (Canter, 1998)

1. Analogs refer to information from existing projects of a type similar to the project being addressed; monitoring information related to experienced impacts is used as an analogy to the anticipated impacts of the proposed project.

4. There are many variations of checklists, with this type of methodology utilized frequently. Conceptually, checklists typically contain a series of items, impact issues, or questions which the user should address.

5. Decision-making checklists are primarily related to comparing and conducting trade-off analyses for alternatives. In this regard, such methods are useful for the synthesis of information in relation to each viable alternative.

6. Environmental cost-benefit analysis (ECBA) represents an emerging method. ECBA supplements traditional cost-benefit analysis with increased attention to the economic value of environmental resources, and to the valuation of impacts of the proposed project and alternatives on such resources.

7. Expert opinion, also referred to as professional judgment, represents a widely used method. Specific tools to facilitate information development include the conduction of Delphi tools, the use of the adaptive environmental assessment process to delineate qualitative/quantitative models for impact prediction, or the separate development of models for environmental processes.

8. Expert systems refer to an emerging method that draws upon the professional knowledge and judgment of experts in particular topical areas. Such knowledge is encoded, via a series of rules or heuristics, into expert system shells in computer software.

9. Indices or indicators refer to selected features or parameters of environmental media or resources which represent broader measures of the quality/quantity of such media or resources. Specifically, indices refer to either numerical or categorized information which can be used in describing the affected environmental and impact prediction and assessment. Indices are typically based on selected indicators and their evaluation.

10. Laboratory testing and scale models refer to the conduction of specific tests and/or experiments to gain qualitative information relative to the anticipated impacts of particular types of projects in given geographical locations.

11. Landscape evaluation methods are primarily useful for aesthetic or visual resource assessment. These are derived from indicators, with the subsequent aggregation of relevant information into an overall score for the environmental setting (similar to number 7).

12. Literature reviews refer to assembled information on types of projects and their typical impacts. As noted for analogs, such information can be useful for delineating potential impacts, quantifying anticipated changes, and identifying mitigation measures.

13. Mass-balance calculations refer to inventories of existing conditions in comparison to changes in such inventories that would result from the proposed action. Inventories are frequently used for air and water pollutant emissions, along with solid and hazardous wastes to be generated.

14. Interaction matrices represent a widely used type of method within the EIA process. Variations of simple interaction matrices have been developed to emphasize particular desirable features.

15. Monitoring (baseline) refers to measurements utilized to establish existing environmental conditions and interpret the significance of anticipated changes from a proposed action.

16. Monitoring (field studies) of receptors near analogs represents a specialized approach, in that it is possible to monitor actual impacts resulting from projects of similar type to the project being analyzed.

17. Networks delineate connections or relationships between project actions and resultant impacts. They are also referred to as impact trees, impact chains, cause-effects diagrams, or consequence diagrams. Networks are useful for showing primary, secondary and tertiary relationships.

18. Overlay mapping was used early in the practice of EIA, with the usage consisting of the assemblage of maps overlaying a base map and displaying different environmental characteristics. The application of geographical information systems (GIS) via computer usage has been an emphasis in recent years. This technology represents an emerging method.

19. Photographs or photomontages are useful tools for displaying the visual quality of the setting and the potential visual impacts of a proposed action. This method is related to landscape evaluation.

20. Qualitative modelling refers to methods wherein descriptive information is utilized to address the linkages between various actions and resultant changes in environmental components. Such modelling is typically based upon expert opinion (professional judgment, as described earlier).

21. Quantitative (mathematical) modelling refers to methods that can be used especially for addressing anticipated changes in environmental media or resources as a result of proposed actions. Quantitative models can encompass simplified models to very complicated three-dimensional computer-based models requiring extensive data input.

22. Risk assessment refers to an emerging tool initially used for establishing health-based environmental standards. It encompasses the identification of risk, consideration of dose-response relationships, conduction of an exposure assessment, and evaluation of the associated risks. Risk assessment can be viewed from the perspective of both human health and ecological risks.

23. Scenario building refers to considering alternative futures as a result of differing initial assumptions. Scenario building is utilized within the planning field, and it has EIA applicability, particularly in the context of strategic environmental assessments.

24. Trend extrapolation refers to methods that utilize historical trends, extending them into the future based on assumptions related to either continuing or changed conditions.

5.0 PUBLIC HEALTH NOTICES AND INTERVENTIONS IN ENVIRONMENTAL ASSESSMENT

5.1 Introduction

The preceding chapters have demonstrated that health practitioners can intervene in the process in many different ways. The potential goals of public health interventions include impact prediction, surveillance, prevention and mitigation, as well as the correction of impacts once they have occurred.

Public health notices and interventions can focus on specific projects, such as the construction of a road or factory, or address the effects of legislation, regulations, programs and policies of an economic nature, which often have a major impact on environment and health.

The tools available are varied and draw on a number of disciplines. What is important, ultimately, is the health professional's ability to use these tools in analyzing and interpreting information. Regardless of how valuable information may be, it must be made comprehensible and useful to the public and decision-makers. The onus is on the health professional to perform this task with respect to the public health component of EA.

The sustainable development framework has been retained as a general criterion for the purposes of public health analysis, which mainly deals with:

- the likelihood that contaminants or anticipated irritants will have an impact on health and quality of life, as well as the ultimate issue of desirable levels;
- the foreseeable equity in the distribution of risks, disadvantages and benefits, and, ultimately, their desirable distribution;
- the impact of the initiative being considered on the preservation of life-sustaining ecosystems and on the services derived from these ecosystems, and, ultimately, desirable impact mitigation measures.

The objective of the public health notice is to contribute to the inclusion of adequate measures to:

- protect public health and safety;

- eliminate, reduce or mitigate environmental and social impacts that have an adverse effect on health and quality of life;

- promote impacts that are beneficial to health and quality of life;

- maintain and improve life-sustaining ecosystems.

This approach is consistent with the objectives of Health Canada with respect to sustainable development (Health Canada, 1997) and the good practices recommended by the OECD (1996). It has also been adopted by a number of governments, including that of New Zealand (PHC, 1995).

This chapter is essentially devoted to providing a more detailed description of the analysis and preparation involved in producing a public health notice.

5.2 *Risk management: a brief history*

1960-1980

The Atomic Energy Control Board (AECB) recently summarized the history of risk management as follows:

> [translation]"... the first *virtually safe dose* proposed in the United States was designed to limit the risk of cancer to one in one hundred million (10^{-8}) for a lifetime of exposure [see Rodricks et al., 1987], the idea being that if the total population of the United States were to be exposed to a virtually safe dose, or a dose very close to it, only one or two persons would be affected among the country's total population (approximately 150 million at the time). Soon after, it became clear that this criterion placed an almost intolerable burden on regulatory agencies charged with guaranteeing the safety of food additives, while ensuring that the considerable advantages of these additives could be exploited. The majority view then became that a risk of one new case of cancer per million inhabitants could be considered negligible. At this rate, only three new cancer cases per year would occur if all Americans were exposed.
>
> Over the course of the next few years, the standard of *one in one million* became institutionalized as an *acceptable* risk and when it became understood in the latter part of the 1960s and early 1970s that ambient exposure carried a risk of cancer, the concept of a negligible lifetime risk (set at one in one million or 10^{-6}) was frequently applied, especially in the United States [Kelly and Cardon, 1984]. Early on, the greatest source of concern was generalized risk, such as that induced by exposure to polychlorobiphenyls (PCBs) or pesticide residues in the environment. Later, the same

> standard was applied to risks that are far less generalized, such as the risk encountered in the areas surrounding industrial sites and hazardous waste disposal sites.
>
> In time it became clear that a risk of one in one million (10^{-6}) was in fact a highly rigorous standard in cases where the number of individuals exposed was relatively small (US EPA SAB, 1992). For the U.S. Environmental Protection Agency (EPA), risk levels equal to or higher than one in ten thousand are considered acceptable in setting maximum levels of contamination by cancer-causing agents in drinking water, when it is technically or economically unfeasible to achieve greater reductions. However, the general view is that risk levels higher than one in ten thousand are excessive, even when very few individuals are exposed, and require the implementation of measures to reduce both exposure and risk (US EPA SAB, 1992)."

Without making this an official policy, Canada and its provinces adopted a similar approach, within their respective areas of jurisdiction. At the time, risk management was generally defined as a decision-making process in which the results of risk assessment were integrated with other considerations. In 1983, the National Research Council defined risk management as [translation]: *a decision-making process involving the consideration of information of a political, social, economic and technological nature, in addition to data concerning risks, in order to develop, analyze and compare regulatory options; the goal of this process is to select the most appropriate response with respect to potential risks that may pose a chronic threat to health* (NRC, 1983, translated in CSE, 1993).

In Quebec, risk management has been variously defined as [translation] *a process for determining the actions and measures required in order to control or eliminate risk* (Cardinal, 1989) or as [translation] *a process designed to integrate the results of risk assessment with social, economic, political and technical data, in order to select the most appropriate option from a public health perspective* (CSE, 1993). For its part, the CCME (1996) has defined risk management as [translation] *the selection and implementation of a strategy to control risk, followed by the monitoring and assessment of that strategy to determine its effectiveness; the choice of a particular strategy can be based on an examination of the information obtained in the course of the risk assessment.* This definition is substantially the same as the one adopted by Health Canada (1997).

Throughout the last few decades, no proposals have been put forward to adopt a consistent approach to quantifying an acceptable level of residual psychosocial risk. It would appear that negotiation practices, external advisories (commissions, government departments, municipalities, and others) and the usual power relationships that exist among the various parties involved are the only formal criteria being used to decide what constitutes an acceptable level of psychosocial risk for communities. However, there are a number of municipal regulations and government guidelines with respect to the most common irritants (noise, odours, dust).

1990 to today

Over the years, this concept of risk management has come under considerable criticism, particularly from industry, environmental groups and academics (NRC, 1994) for, among other things, the highly variable cost of measures undertaken with respect to health (from $200,000 to $5,000,000,000 per life saved, for example). Current thinking is shifting risk management toward an approach and a definition broader than those traditionally employed. In recent years, several organizations have reviewed and analyzed the conceptual framework put forward by the NRC in 1983, including its principles, organizational aspects and methodological elements (EPA, California, 1996; National Research Council, 1994, 1996; Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997a, 1997b).

In 1997, the Presidential/Congressional Commission on Risk Management and Risk Assessment issued its two final reports (1997a, 1997b). The Commission was created by the American Congress in the wake of changes made to the Clean Air Act. The Commission was given the mandate to conduct a study into the political implications, as well as the uses of risk assessment and risk management, in programs created under federal law to prevent cancer and other chronic diseases that can result from exposure to chemical substances.

The work of the Commission made it clear that the traditional approach to assessing and reducing risk was in need of change. The Commission issued numerous recommendations and introduced new dimensions to traditional approaches used in risk management, as well as a broader and more integrated definition of risk management itself.

> *Risk management is the process of identifying, evaluating, selecting, and implementing actions to reduce risk to human health and to ecosystems. The goal of risk management is scientifically sound, cost-effective, integrated actions that reduce or prevent risks while taking into account social, cultural, ethical, political, and legal considerations.*

The framework for risk management proposed by the Commission comprises six steps: developing a broad definition of the problem; analyzing the risk; examining options for addressing the risk; making decisions; taking actions to implement the decisions; and conducting an evaluation of the actions' results. Every step is conducted in cooperation with stakeholders, beginning with efforts to develop a definition of the problem. In addition, the approach may include an iterative process, requiring that previous steps be repeated if new information is uncovered at a given stage.

Figure 5.1 Frame of Reference Proposed in the United States

	Problem/context	
Evaluation		Risks
	Engage Stakeholders	
Actions		Options
	Decisions	

Source: The Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997. *Framework for Environmental Health Risk Management.* Volume 1. p.3.

The proposed framework emphasizes cumulative risks and takes into account the benefits, costs and social, cultural, ethical, political and legal aspects of risk reduction options. According to the Commission, the advantages of this framework is that it provides an integrated approach to solving public health and environmental problems; it ensures that decisions rely on the best scientific evidence; it emphasizes collaboration, communication, and negotiation with the public; it produces risk management decisions that are more likely to be successful; and it accommodates new information that may emerge at any stage of the process.

The "risk" stage refers to the risk assessment process, but it should also include and emphasize the goals of risk management. Analysts must make use of scientific information in combination with their own professional judgement. The result of risk assessment is a "characterization" or "estimation" of risk, which should provide stakeholders and decision-makers with all relevant information.

The integrity of assessments must be ensured by enlisting external reviewers. To the greatest extent possible, the analysis conducted should address such dimensions as the multisource, multimedia, multichemical and multirisk contexts. It should also seek to identify the perceptions of stakeholders and take these into account in presenting results.

We are witnessing the formal inclusion of psychological and social components as integral parts of the risk management process and as key criteria in decision-making, replacing the perception that these are mere irritants which interfere with a process conducted among experts. The review of the risk management process which is currently underway at Health Canada is expected to give considerable weight to these prevailing trends, some of which have already been incorporated into the Department's practices.

5.3 Connection with environmental assessment

Risk management, an essential component of the public health notice, is also a key element in the complex negotiation process called environmental assessment. The first quality of a public health notice is its existence and the second is clarity. Frequently, the critique of an impact study results in a vague paper with no definite conclusion. Therefore, it is important to take a clear position as to what constitutes an acceptable risk and what does not, and to indicate what improvements are necessary and desirable from a public health and public safety perspective. The section that follows deals with project analysis, although the proposed approach can also be applied to programs and policies.

One noteworthy contextual element is the fact that public health notices deal with public facilities or factories with a normal life-span of 25 to 50 years, and sometimes more, as is the case with large factories, mines and dams. The timeframe for policies, programs and important fiscal initiatives is often shorter, with provisions made for review after 5 or 10 years. Once established, however, programs tend to endure and often entail a succession of construction projects, demolitions and renovations, with their attendant environmental and health impacts. Public health notices must take the longevity of projects into account and make rigorous requirements to protect public health.

A public health notice cannot take the place of the authority responsible for making the final decision with respect to specific projects and policies. Rather, it must take a rigorous, independent and clear position in favour of mitigating the adverse aspects of initiatives and promoting the benefits. A variety of criteria have been proposed for guiding decision-making and developing a position. The standard public health criteria are presented in volume 1 of this Handbook, and in the international study (Sadler, 1997). It is also useful to contextualize public health within the framework of the general criteria used in environmental assessment. An excellent summary of these criteria was recently produced by the Commission for Environmental Cooperation, a body created under NAFTA (CEC, 1997) to assess the significance of transboundary impacts requiring a comprehensive review. The CEC list can also serve more general purposes, as demonstrated by Box 5.1. It also integrates and gives equal importance to environmental, social, health and economic considerations, in keeping with the approach developed in this Handbook.

Box 5.1 Factors for determining significant adverse transboundary impacts

The determination of whether adverse transboundary environmental impacts are significant involves consideration of the following factors:

1. *Context:* Context factors potentially relevant to the determination of significance of a transboundary environmental impact include, for example:

- the potentially affected human populations and vulnerable segments of the population (e.g. children, elderly persons);
- geographic extent (region and localities);
- ecological context;
- unique characteristics of the geographic area (e.g. proximity to historic or cultural resources, park lands, wetlands, wild and scenic rivers, or ecologically critical areas);
- where provided by the Potentially Affected Party, standards regarding the protection of health or the environment as specified in international, national and subnational legal instruments;
- probability of occurrence;
- scientific uncertainty.

2. *Intensity:* Intensity factors potentially relevant to the determination of severity or magnitude of transboundary environmental impacts include, for example:

- degree of toxic and other impacts on public health or safety;
- degree to which environmental impacts involve unique or unusual risks;
- degree to which a project establishes a regulatory precedent, or causes the issuance of a permit in a new area, and therefore may cause future projects to be carried out with significant transboundary environmental impacts;
- duration, potential for recurrence and frequency of impacts;
- degree of irreversibility of impacts;
- relationship to other projects which, even though individually insignificant, cause cumulative impacts, or can reasonably be anticipated to cause significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment; it is independent of whether a project is temporary in nature or is broken down into small component parts;
- degree to which physical or biological impacts of the project may adversely affect important historical or cultural resources, or traditional uses by indigenous people of cultural, historical and natural resources;
- degree to which a project may adversely affect threatened or endangered species or their habitats which have been determined to be critical;
- degree to which biodiversity is affected;
- degree to which natural ecological systems and landscapes are transformed;
- degree to which a project may foreclose or reduce the quality or availability of renewable and non-renewable resources.

5.4 Drafting a public health notice

The following elements should be included in public health notices:

- a review of the availability of data, a determination of the quality of data and an assessment of the degree of reliability in estimating both adverse and beneficial impacts (health and social components);

- a comparison of the risk levels obtained with current standards, or with levels generally considered to be safe;

- an identification of grey areas and adverse impacts for which no social consensus or standards exist;

- a review of comments and positions of the various publics and populations that will contribute to determining the social acceptability of the project;

- a summary of benefits and disadvantages and a statement on the acceptability of the project from a public health perspective, which addresses the likelihood of physical, psychological and community health impacts, the equity in their distribution, as well as ecosystem preservation.

5.4.1 Review of existing data

The matrix presented in Appendix 1 can assist in evaluating the completeness of the available data on possible adverse health impacts. In short, the object is to determine whether the information provided by the proponent for each of the cells in Figure 6.2 appears to be:

- complete (is the literature review up-to-date?);

- accurate (are the interpretations those of the authors of the studies or those of the proponent?);

- transparent with respect to any uncertainty or weakness in the basic scientific data (unknown or little- known risks are clearly identified), or any limitations of the prediction model that was used.

Figure 5.2 Matrix of adverse health impacts

AGGRESSOR /EXPOSURE	Type of aggressor	Environmental impact	Zone of influence	Monitoring measures	Standards or recommendations	Health impact	Population at risk	Probability of occurrence and uncertainty	Biological indicator/ environment (follow-up)
Technological hazard									
Gaseous or air emissions									
Liquid emissions in water									
Solid emissions in soil									
Irritants									
Indirect psychosocial impacts									

Assessing the availability and reliability of data on the positive effects of a project is essentially the same activity, although the emphasis is usually reversed, with socio-economic aspects gaining greater prominence. The terms employed are different and the categories of impacts vary as well within a given field (Table 5.1).

Table 5.1 Adverse and positive impacts

Adverse impacts	Positive impacts
Damage, emissions	Ecosystem component
Irritants	Quality of life component
Indirect psychosocial impacts	Socio-economic component

Some projects help reduce environmental risks to health; for example, when an outdated coal-fired electric power plant is replaced by a gas turbine, or when emergency health care services are improved by providing more rapid means of transportation. Figure 5.3 summarizes these positive impacts.

Figure 5.3: Matrix of positive health impacts

Expected benefits	Type of impact	Zone of influence	Population affected	Probability of occurrence & uncertainty	Monitoring & follow-up measures	Health impact	Compliance with recommendations or S.D. principles
Socio-economic component • revenue/taxes • employment • public • infrastructure • perceptions • social cohesion							
Quality of life component: • landscape • recreational uses • cultural uses							
Ecosystem component: • water • air • soil • biospecies							

Assessing the quality of data dealing with socio-economic or environmental impacts is more delicate since health professionals often do not have access to the necessary expertise. However, this exercise remains an essential part of formulating public health notices, because it is important to determine whether the project justification is consistent with current policy, and whether the social or economic studies conducted are in keeping with current methodological standards. By referring to their own knowledge of the environment and consulting with experts and public health officials, practitioners can normally acquire a fairly solid understanding of the subject.

Frequently encountered pitfalls include:

- When no official public policy exists for overseeing a given project, formulating a justification becomes more difficult; a project (such as the development of a large hog farm) can sometimes serve as a test for other similar projects to come. Situations like these require closer scrutiny.

- Economic studies deal only with the spin-offs (in terms of employment) of the monetary resources that will be spent. Caution is advised in dealing with these "pre-scientific" studies, since any expenditure can bring about job creation to a greater or lesser extent, depending on the sector involved. Generally speaking, health care services are among the sectors that create the most employment, with heavy industry at the other end of the spectrum. If the main argument in favour of a project rests on the study of economic spin-offs, this is a clear sign of a weak argument.

- When more exhaustive economic studies are available (e.g. cost-efficiency, cost-benefit), the debate will centre on a number of methodological assumptions that are essential to any study. Examples include the discount rate to be used, the project timeframe, and the area being studied. In this situation, it may be useful to ask the proponent to present several scenarios in which different levels are used for a number of key variables. Thus, the soundness (or weakness) of the models used for these variables can be assessed. Consulting with independent experts can also be helpful here.

- The distribution of benefits and disadvantages almost invariably gives rise to problems. Local authorities should always be consulted to determine whether the proponent's proposals and requirements are realistic. The employment component can be a delicate area: companies often require a high level of technical training, which can be difficult to find in some centres. The impact on municipal and regional services (water, waste management, fire department, police, roads, health services, etc.) is frequently underestimated in these studies. In order to avoid future disappointment and to temper the enthusiasm in some municipal quarters, complete transparency regarding any uncertainty in predicting impacts is advisable.

The review of available data should conclude with a notice regarding the quality of the data, as well as requests for more detailed information or additional studies judged to be crucial for the future.

5.4.2 Making comparisons based on existing standards

When standards already exist, the task becomes considerably easier. In conducting environmental assessments, however, it is important to remember that the life-cycle of a facility can extend over many decades. Consequently, adherence to the strictest standards is advised when dealing with new facilities. The strictest standards are generally found in Western jurisdictions with a high population density (e.g. California, Europe) and pollution levels that are higher than those in Canada.

Adopting this approach avoids the risk of using outdated standards as a goal for decades to come. With most new technology, it is possible not only to comply with the strictest standards but often to achieve emission levels that are 100 to 1,000 times lower. Since the trend in scientific studies conducted over the past 30 years is to detect increasingly subtle effects at very low levels of exposure, providing a margin of safety for the long term would appear to be a good idea.

When no standards exist, the situation varies depending on whether a risk to health is deemed to be serious and irreversible (for example cancer or death) or less severe (eye irritation, discomfort caused by noise, etc.), or whether the risk at issue is a complex one affecting an entire community (as in the case of rapid development).

5.4.3 Making comparisons in the absence of standards

Acceptable risk levels which have been incorporated into standards may be applicable here. Standards generally provide for levels of acceptable risk on the order of one new death per million for a lifetime of exposure (70 years), a level rightly considered to be very safe when applied to a small population, which is most often the case.

For example, if 1,000 people live in the vicinity of a smokestack and are thereby exposed to a carcinogenic contaminant, one would theoretically have to wait 70,000 years for a case of cancer to occur. Therefore, such levels would appear to be adequate in the absence of standards. Levels of exposure lower than this would be considered negligible, meaning that no corrective measures would be required with respect to the project under review. It should also be mentioned that epidemiological methods cannot measure such risks, even when health status is rigorously monitored. Even if such risk levels were measurable, data on numerous other potential cancer causes extending over a period of 60 to 70 years would be required, including lifestyle habits and heredity. The same disease can result from many different causes and the human body has a limited number of ways of manifesting disease. For example, one could examine a hundred organic or anthropogenic chemicals associated with liver disease, while overlooking such things as infectious agents, alcohol consumption and nutrition.

In 1989, the Dutch government proposed that explicit limits be set for judging the acceptability of risks. This risk management framework (VROM, 1989) was subsequently made part of the Netherlands' environmental policy. This global approach to risk management has the advantage of being comprehensive and of setting clear limits which facilitate decision-making. For almost ten years, this framework has proven appropriate in the vast majority of risk management situations (de Boer, 1997). Since 1993, it has also been recommended as a general reference for public health branches in the province of Quebec, where it has proven equally useful. It is summarized here as a guide for public health practitioners, who may find it helpful as a template for evaluating risk levels obtained through impact studies. Readers interested in the rationale underlying these levels may wish to consult the original document (VROM, 1989), which is also available from the CSE (1993).

Individual risk

This approach also uses as a threshold one new death per million persons exposed for life (10^{-6}) as a point of departure. Then a *negligible* risk level is established at 1% of the base level, or one additional death per 100 million (10^{-8}). These levels are applied for individual risk associated with technological accidents or chemical substances newly introduced into the environment.

The proposed approach also requires that practitioners take into account the fact that new risks are added to existing risks. In order to factor in this chemical or technological *background*, a level of one new death per 100,000 persons exposed for life (10^{-5}) has been suggested as an *acceptable* level for all combined risks within a given category (chemical, technological, radiation). Therefore, exposure to ionizing radiation is also included here. Exposure is calculated on the basis of a 24-hour day in both cases, which ensures an additional margin of safety.

Collective risk

For collective risk, defined as the probability of 10 or more deaths, the *acceptable* level is set at 10^{-5}/year, and at 10^{-7}/year for 100 deaths or more, and so on. Any situation in which the probability is greater than 10^{-5}/year necessitates the implementation of risk reduction measures.

Chemical substance thresholds

When chemical substances have a threshold beneath the level at which toxic effects can be measured, this threshold (NOEL) is used, along with the standard margins of safety. This is the standard practice in Canada; however the methods used to calculate margins of safety can vary in different countries, for different forms of exposure, etc.

Ecological risk

The Dutch model defines acceptable risk to the ecosystem as a level of lethal concentration which eliminates 50% of test organisms (LC 50) for major hazards, and an LC of 5% for chronic exposure to chemical substances. In the latter case, 95% of the species in an ecosystem would be protected. These standards apply to new situations and are to be considered a goal for existing situations.

5.4.4 Comparisons based on the principles of sustainable development

No standards exist to determine what percentage of new employment should accrue to local residents or whether the integrity of the landscape is being adequately protected. A number of authors have pointed to an established practice among proponents, which consists of ensuring that 10 to 25% of project-related jobs accrue to the host community. This would appear to be a threshold that significantly improves a project's acceptability (Hobart, 1983, 1984). Of course, higher levels of employment spin-off are often achieved, depending on the human and entrepreneurial resources available in a given community. Some companies also implement compensation policies with respect to residual impacts, establishing a level ahead of time. (Hydro-Québec reserves 2% of capital costs for community-based projects.) More recently, other formulas for gaining greater host community involvement have been put forward, such as local share ownership or royalties for the use of natural resources.

However, complying to the greatest extent possible with the concrete principles presented in section 3.5 should, ideally, help to maintain a strong sustainable development focus. This type of analysis will take a different form for a project (such as a cogeneration plant) than it would for a program or policy.

For example, a factory or highway development project cannot be expected to use non-renewable resources at a rate that would permit their eventual replacement with other types of resources, because that is not its role. Consequently, exercising good judgement is crucial in selecting the proper criteria. However, when one is asked to comment on the government's energy supply policies, examining this criteria is essential.

Ultimately, sustainable development depends on an equitable distribution of benefits and disadvantages across a given population, and among regions and generations. The role of public health practitioners and agencies is to monitor the views of groups within the population and to take into account a number of inter-regional considerations (transportation of pollutants over great distances, contamination of the food chain, etc.), as well as intergenerational issues (long-term risks, resource or ecosystem depletion, etc.).

In summary, specifying clear risk levels and criteria for intervention are useful aspects of preparing a public notice, since this provides a set of guidelines, however approximate, as well as comfort and discomfort zones for public health professionals and proponents. The levels presented above are fairly representative of the current situation in industrialized nations, but will require a significant effort in a number of economic sectors. Exceptions to these levels can also be made to correct existing high-risk situations (10^{-4} for example) and achieve a lower level (such as 10^{-5}) at a reasonable cost. The levels indicated also compare favourably with several other social risks (cars, sports, lifestyle habits, etc.) which are more closely linked to individual choice or past choices.

5.4.5 Identifying grey zones and other adverse impacts

A public health notice should identify any point that is contentious from a health perspective. After reviewing the risk levels outlined in the preceding section, the practitioner may conclude that actual risk levels appear to be high for one or more contaminants. It should be kept in mind that the method selected to analyze the risk can leave one exposed to criticism; consequently, any deficiency should be clearly pointed out.

Normally, several other risks of greater or lesser toxicity and with a degree of probability often approaching 100% will be encountered. These risks most commonly come in the form of:

- irritants (noise, unpleasant odours, traffic, etc.);
- psychosocial impacts (perceptions of the project, employment, revenue, municipal services, development of the affected community, etc.);
- impacts on life-sustaining ecosystems (water, air, living organisms).

The role of health professionals consists of correctly identifying these impacts and verifying the accuracy of forecasts and the adequacy of proposed mitigation or compensation measures.

There are, in fact, many different types of measures for attenuating impacts, and it is often advisable to consult experts in each of the contentious areas identified to ensure that irritants are minimized. With some projects, such as open-pit mines and hog farms, the nuisance factor becomes highly contentious. It is not uncommon to find proponents who show little concern for the disturbance they are causing their neighbours, and who often fail to meet municipal, provincial, federal or international standards. Due to past experience, the public's perception of such projects is often very negative; this can make it difficult to introduce new technology, even when it promises to perform very well.

Psychological and social impacts constitute another crucial area of intervention for public health practitioners, one that merits considerable attention. Public health practitioners and agencies need to publicly acknowledge that the community's perception of a project is not only legitimate, but also capable of inducing its own health impacts. Any perception, be it negative or positive, is likely to influence the types of impacts that are felt in the community, in terms of employment, social cohesion, taxation, etc. Economists are beginning to acknowledge that a healthy community is an important part of a well-functioning economy (Putnam, 1994). Social cohesion, civic involvement, mutual aid and many other similar activities bind communities and make it easier to adapt to large or small-scale changes. Examples can be found of well-planned and competently managed projects that have generated very positive social benefits despite their size. Oil development projects in the North Sea are one example (Hill, 1998).

Conversely, the social and economic upheaval currently experienced by many of Canada's First Nations as a result of development projects, has produced a number of adverse social impacts and negative perceptions (Grondin, 1994).

Impacts on life-sustaining ecosystems also need to be pointed out to public health authorities. With the increase in human economic activity and its attendant impact on ecosystems (see Figure 6.2), it is important to ensure that these ecosystems remain intact or that future losses are completely replaced in the area sustaining the impacts or elsewhere.

Figure 5.2 World ecosystem in relation to the economic sub-system

A. Ecosystem and economic sub-system in 1900

Finite global ecosystem
Expanding economic sub-system

Primary materials	Production - $60 trillion in goods and services	Secondary materials
- energy - resources		- pollution - waste
Reuse/recycling of materials		

B. Ecosystem and economic sub-system in 1990

Finite global ecosystem
Expanding economic sub-system

Primary materials	Production - $20,000 trillion in goods and services	Secondary materials
- energy - resources		- pollution - waste
Reuse/recycling of materials		

SOURCE: CCME 1993

5.4.6 Reviewing other positions

It is important to cite, with the authors' permission, the comments and positions expressed with respect to the project by various organizations and key individuals. This review can also encompass official documents (relating to public hearings, for example), and media coverage. Public health notices should also mention the experts and managers who were consulted by public health authorities, as well as the reports and other relevant documents that were reviewed.

5.4.7 Summary of benefits and disadvantages

Taking a clear position on the acceptability of a project requires sound professional judgement. A number of useful criteria for making this judgement have already been suggested in earlier sections of this Handbook.

In summary, the proposed approach is based on the principles of sustainable development and seeks to achieve extremely low levels of contamination, to distribute benefits and disadvantages equitably, in a manner that is widely accepted by the community, and to preserve existing ecosystems.

With experience, one discovers that projects often have elements that are acceptable, as well as others that are questionable or that require major modification. These aspects, as well as the work that remains to be done, should be pointed out without hesitation, keeping in mind that the role of public health authorities is not to address the engineering or other solutions required to solve a problem, but rather to indicate desirable overall directions.

A measure of self-censorship and self-deprecation is also in order. We have seen many mega-projects undergo substantial revision for reasons of public health or be halted completely because of public opinion. At times, environmental authorities seem to overlook the need to protect ecosystems: some help and support for reasons of human health can surely do no harm.

5.4.8 Social acceptability

Attempting to determine what will be socially acceptable can be difficult, as politicians and proponents often discover. It is possible, however, to identify factors that help anticipate controversy, and others that can facilitate project acceptance. A useful review of several waste management projects and programs undertaken in Canada (Toronto, Montreal, Quebec City, Halifax) and in New York State, identified some of these factors (Delisle, Transfert Environnement, 1996). Waste management is in fact a good example, since it gives rise to many different risks, irritants, perceptions and social and ecological impacts.

Delisle identifies two particularly sensitive factors that can easily become irritants and trigger resistance to a project. These are:

- accumulated frustration, and
- symbolic triggers.

Accumulated frustration can take many different forms. It can range from the perception of social injustice to the anger that sometimes spills over in areas where too many contentious projects have been developed or in areas that are already polluted (such as industrial zones), prompting citizens to reject any further development. When this type of "psychosocial saturation" sets in, even projects that could improve current conditions are met with suspicion and rejection.

Symbolic triggers are components of a project or facility that create controversy. In the case of waste management projects, the authors point to a number of symbolic triggers, including the importing of waste, the involvement of a multinational corporation, the presence of smoke stacks or hazardous waste, the degradation of the visual aspects of the landscape, and unpleasant odours. These reactions are entirely human. It is also likely that only the good neighbourhoods are spared offence--such developments cannot occur there, due to zoning laws and the price of land.

Many examples of this type of meta-analysis are available. An awareness of the factors likely to provoke resistance in a given context can assist in designing projects that will find acceptance and in presenting such projects as part of a facilitating process. Clearly, respect for collective priorities and pro-active social attitudes are key ingredients of sound social management. Collective priorities have now been integrated into the environmental component of EA and into certain aspects of sustainable development, a fact which is reflected in many laws, regulations, professions, surveys, etc. Governments and corporations are also being called on to adopt a coherent approach. Issues that go beyond pollution management and recycling now need to be addressed, including resource conservation, reuse of formerly contaminated sites, and community involvement in the development of environmental management systems. There is more involved than simply providing sound management. Indeed, the changes that are taking place point to new social choices and a new collective vision.

Pro-active social attitudes, a subject much discussed by the EPA (1988), imply honest and credible behaviour and attitudes on the part of proponents, as well as a genuine receptivity to the expectations of the community. However, much headway remains to be made in this area.

6.0 CREDIBILITY AND COMMUNICATION

6.1 Effective communication tailored to expectations

In a study examining the implementation of approximately twenty incinerator projects, Konheim (1988) observed that the standard risk assessment process failed to address the concerns being voiced by the public. Konheim outlined ten recurring questions expressed by citizens and their representatives (Box 6.1). These concerns are highly consistent with the issues that commonly arise with most large projects.

Konheim also reports that when an incinerator project was proposed in the New York area, a citizens advisory committee was more comforted by the qualitative conclusions of two physicians from Mt. Sinai School of Medicine, indicating that health effects of the plant were "minimal" and "non-detectable", than they were by the quantitative predictions of a scientific expert to the effect that the risks of dioxins from the plant would be in the range of 0.24 to 5.9 $X 10^{-6}$. This suggests that the public's expectations are more often qualitative than quantitative in nature.

In their guide for government risk communication, Chess et al. (1988) stress the importance of understanding community expectations, developing and maintaining credibility, controlling the timing of disseminated information, interacting with the community and taking the time to explain the various aspects of risk assessment.

Box 6.1 Typical questions raised by the public when faced with the development of incinerator projects

1. What are the specific risks compared to the benefits of the project? Is the risk to each group worth the benefit gained? What are the benefits and risks of alternative solutions? What are the benefits and risks of taking no action?

2. How did you calculate the risk? Is there one standard way of doing it, or are there several? Is there a prevailing consensus on the basic facts in the scientific community? Or are there distinguished dissidents?

3. Did you base your calculation on data from facilities already in operation, or is the data base theoretical?

4. If you based the data on already-operating facilities, were they very similar to the proposed project? If not, how would their differences alter the analyses?

5. Does the design of the facility make the risk as low as it possibly can be? Can the facility be updated later if new ways are found to lower the risk?

6. Who in the community bears the burden of risk? Are older, younger, and sick people more at risk?

7. What is the chance of a serious accident? If one occurred, what would be the worst possible impact? How often do accidents happen in currently operating facilities? Will their likelihood increase over time? What is their magnitude? Would the effects of an accident be irreversible? What provisions have been made to handle accidents?

8. Will risks be identifiable? Who will monitor the performance of the plant? Can the risk be reduced?

9. Can the public influence how the facility is designed and operated?

10. Does approving the project mean foreclosing future, potentially less risky, options?

Source: Konheim, C.S., Risk Communication in the Real World, Risk Analysis, Vol. 8, No. 3, 1988.

According to Covello (1992), the key to effective communication is the confidence and credibility of the individual or organization conveying the message to the public. Studies have shown that organizations and individuals perceived as being credible in matters of risk assessment include health professionals, university professors, the media, non-profit health organizations and respected local citizens who are considered to be impartial and well-informed about risks. The research demonstrates that the general population views doctors and academics as being motivated by noble goals, the former being dedicated to healing and the latter motivated by the quest for knowledge and truth. Both groups are perceived as being economically independent from the organizations that hire them as consultants, and therefore unconstrained in rendering their professional judgment.

Covello (1992) identifies four factors that influence the perception of confidence and credibility:

- *The perception of empathy and caring:* This would seem to be the most important factor. Does the communicator give the impression that he/she is interested in health, safety, the environment and fairness? Does he/she take the time to listen to his/her audience? More often than not, the public makes its mind up about this factor from the initial contact. Once the public has passed judgment, perceptions be very difficult to change.

- *The perception of competence and expertise:* This perception is largely influenced by the past accomplishments of a government organization or agency and by factors that relate to the communicator, including training, experience, knowledge and verbal skills.

- *The perception of honesty and openness:* This perception is influenced by actions, words and non-verbal communication. A communicator who is unable to meet the gaze of others, or the placing of physical barriers between the communicator and his/her audience, are forms of negative non-verbal communication.

- *The perception that the communicator is dedicated to the cause:* This perception arises from the impression that the communicator is a hard worker who diligently strives to achieve goals connected with health, safety and environmental protection. The audience normally forms this impression based on various verbal and non-verbal cues: Is the communicator available outside of office hours? Does the communicator remain for the entire public meeting?

Such studies are extremely useful in understanding the nature of effective communication. They suggest that successful risk communication is a complex art that requires skill, knowledge, training and practice. They also suggest that risk communication involves intrinsic limitations, even when the communicator possesses all these qualities. Credibility and honesty must be present from the outset.

Exchanges between citizens' committees/representatives and risk assessment practitioners during the public consultation phase is another key component of successful communication. In addition to helping experts gain a better understanding of the community's needs and expectations, citizens' representatives can play the role of risk communication facilitators. The mere fact that citizens are given the opportunity to review the risk analysis process enhances credibility.

Citizens' committees also play an important role in examining issues of surveillance and environmental monitoring with respect to risk. It has been noted that the public is generally less fearful of risks over which it feels it has the ability to exercise some control. Involving community representatives constitutes a definite investment: when a future course is charted and decisions made, the public will recognize that it was not excluded but, rather, made an integral part of the process (either directly or through its representatives).

Where the health network is concerned, a number of issues need to be considered in coordinating public participation. These include:

- the specific risk evaluation context;
- respecting data confidentiality (when necessary);
- respecting the stakeholders involved in the process;
- avoiding any possible bias that might give rise to criticism and undermine credibility.

Ideally, public participation should be generated and encouraged by the organization responsible for managing the process. Public health organizations should always support the involvement of citizens.

Those charged with communicating risk have an interest in translating numbers (often expressed as a fraction over several thousand or several million) into an order of magnitude that will be more accessible to the general population. For example, Carrier et al. (1991) have estimated that the average individual risk of cancer for the 6,800 citizens residing less than 500 metres from the Des Carrières incinerator in Montreal is 1 in 2.04 million. This somewhat abstract assessment has been translated into a collective annual risk of one chance in 300 (for a population of 6,800) after 70 years of incinerator operation. In other words, it would take 300 years to be sure that one case of cancer among 6,800 individuals developed as a result of incinerator operations. Mathematical conversions of this kind can help the public better understand communicated risk levels.

Risk comparison can also assist in putting a specific situation into context, although this approach has both advantages and disadvantages. In their Handbook for plant managers, Covello et al. (1988) organized 14 types of comparisons into 5 categories, based on their likelihood of success with the public. Selecting one of these categories over others should be done with caution, since some risk comparisons are less acceptable than others and may in fact have little to recommend them. The various categories are outlined in Appendix II of this Handbook. While the risk comparison approach is not universally endorsed (Rahm-Crites, 1998), a number of authors recognize the usefulness of comparisons, pointing to the evolution of the concept of risk and the maturity of the public. The key, then, is the ability to adapt one's approach to the target audience.

Whenever possible, the preferred approach is to use measured or estimated concentrations of substances in the environment and to compare these with concentrations deemed to be acceptable based on toxicological and epidemiological studies.

It is also important to specify whether risks are acute or chronic and to address the probability of occurrence for each substance under review.

Regardless of the numeric value attached to a risk, it is impossible to express risk without specifying:

- any uncertainty associated with obtaining these values;
- any uncertainty associated with the extrapolations made (high dose/low dose, animal experiments and extrapolations for humans);
- that the risk is not uniformly distributed throughout the population, that some individuals will have a greater exposure (in terms of concentration or duration of exposure); and (in the absence of specific risk estimates for particular sub-groups within the population), that some individuals will manifest a greater sensitivity when exposed.

The seven rules of effective risk communication recommended by the EPA (1988) provide a good summary of the desired approach:

1. Accept and involve the public as a legitimate partner.
2. Carefully plan and evaluate your efforts.
3. Listen to the public's specific concerns.
4. Be honest, frank and open.
5. Coordinate and collaborate with other credible sources (organizations or individuals).

6. Meet the needs of the media (be open and accessible).

7. Speak clearly and with compassion.

If the communication of risks and results in EA still seems somewhat nebulous to readers, they should know that they are not alone! This was also the conclusion of several organizations and researchers cited in a recent methodological review (Rahm-Crites, 1998). Their conclusion was that this field is still at the experimental stage and that solid information on effective and efficient approaches is lacking.

Still, it is important to invest in two key areas, which are preparation and credibility. Both of these areas are examined below.

6.2 Preparing a communication strategy

Effective communication requires careful planning. This involves several essential steps:

- *Ensure that the notice is specific with respect to risks/benefits and proposals:* the magnitude of the risk to be communicated, the benefits involved and the options to be proposed must be clear in the mind of the communicator.

- *Establish communication objectives:* risk communication objectives should be clearly defined. Is the purpose of the message to inform the public about a risk to health? Is the purpose to improve understanding? Does the message imply that a change in behaviour is in order? Does the public health notice propose new options?

- *Identify the various target audiences:* Identify the target population for risk communication and segment the various groups within that population. Do not overlook professional audiences (public servants, doctors, engineers, etc.), including your own colleagues.

- *Remain mindful of the socio-cultural environment:* A solid understanding of the prevailing values of a community and its subgroups is important since it enables practitioners to choose the means of communication that are best suited to social (and cultural) preferences about information dissemination. This step allows for necessary adjustments with respect to power and information dissemination structures.

- *Select an approach that is appropriate for the target groups and the socio-cultural environment:* This can take the form of oral, written or visual communication, or a combination of all three. It is also important to identify the individual (or individuals) most likely to communicate the message successfully. Four communication techniques are available: public relations, paid advertising, resource materials and community-based activities.

- *Public relations* refer to activities conducted with a view to obtaining the free cooperation of individuals or the media. Press conferences, letters, open-lines, radio and television programs, exhibits, information booths and contests are some examples of activities falling into this category. Working with the media can be an easy way to convey a message to a large audience, given the considerable credibility the media enjoys with the public. However, since the media controls content, problems can sometimes arise.

- *Paid advertising* includes any form of promotion in the press and electronic media (radio and television), including community, commercial, local, regional and national media. This provides a way of reaching selected groups but often at a substantial cost.

- *Resource materials* include print and audiovisual tools such as posters, brochures, slide presentations, video and instructional games. This approach facilitates the inclusion of more complex elements. However, the method of dissemination and the target audience must be chosen with care. Again, significant costs are sometimes involved.

- *Community-based activities* are defined as any direct communication with a target audience. Public assemblies and information sessions fall into this category. Involvement in community events can be another useful way of getting a message across. Generally speaking, this technique can have considerable impact since it appeals to community values and the need for identification. The cost involved is usually low.

Based on the situation at hand and the objectives pursued, a combination of these techniques can also be effective.

- *Prepare the message:* Draft press releases, additional information, letters of invitation to public meetings and any other material to be disseminated, and transmit these to the various target audiences.

- *Implement the communication program:* coordinate activities and establish schedule targets.

- *Evaluate the impact of the communication strategy:* As much as possible, the effectiveness of the communication strategy and its impacts (including any negative consequences) must be assessed. Evaluating the process can assist in making adjustments to a strategy already underway or in improving future communication strategies.

Some public health stakeholders tend to believe that their role is solely a matter of communicating information to the public in an honest, easily understood manner. However, this may lead them to overlook a number of factors affecting the perceptions held by individuals. More often than not, this kind of oversight leads to conflict and the organization's credibility being called into question. (Goldberg, 1992).

The involvement of citizens' committees or citizens' representatives with public health professionals can help ensure success in establishing a dialogue with the public. It is important to remember that communication also involves listening to the views of others. Frequently, the communication of a public health notice or risk is the final step in an arduous process in which time constraints often play a role. In spite of all this, a way should be found to give it the time and energy it requires.

6.3 Credibility

Credibility is difficult to establish and can easily be lost. It remains the key ingredient of successful communication.

Organizations and individuals must employ a variety of means to develop and maintain their credibility. These include maintaining a high level of scientific knowledge, competently using research methodologies, and maintaining a consistent presence and a steady dialogue with the community and organized groups.

Another essential aspect is having an independent mind and rendering balanced judgements, while maintaining an exclusive focus on public health. That focus forms the very basis of the health professional's mandate, although it can be difficult to remain mindful of this when dealing with cases in which the emphasis is on economic or environmental considerations. Practitioners must remain firmly rooted in the public health field and address other fields through questions or requests submitted to the competent authorities.

Box 6.2 presents a series of ethical principles that can useful in conducting environmental assessments.

Box 6.2 Useful ethical principles for environmental assessment

In fulfilling their role, health professionals must:

- perform their work in accordance with the most appropriate, tested and up-to-date scientific information and methods;
- avoid all forms of discrimination, in accordance with the law;
- show discretion and respect for the rules of confidentiality under existing laws and regulations (with respect to both information on paper and electronically-processed information);
- exercise their functions in an impartial manner;
- avoid any real or apparent conflict of interest, meaning any situation in which practitioners or organizations have ties with parties whose interests run counter to the interests of public health.
- ensure that, in any circumstance, the results of the public health risk assessment will be divulged at the proper time, if necessary;
- promote ongoing training and the development of expertise by sharing experiences and knowledge.

7.0 CONCLUSION

In conclusion, it is important to emphasize that a number of policy positions developed in recent years support the approach advocated in this Handbook. These include the Rio Declaration, as well as numerous charters and declarations around the world, under the sponsorship of international organizations, including the United Nations. Although these policy statements concern us all, it is crucial that our own leaders take similar steps. In fact, this has taken place in Canada, even though it seems to have gone unnoticed: in December 1996, every provincial and federal minister of Health and the Environment signed on to an important declaration with unavoidable implications for the environmental assessment process (see Box 7.1). This declaration gives greater legitimacy to the active involvement of health professionals in environmental assessment. It also supports the approach advocated in these pages, which is to expand the role of public health beyond the physical health component, to include both the social and ecological components. The next phase, which is the implementation of these principles, will be the most difficult but also the most rewarding. Good luck in your work.

Box 7.1: Principles for health/environment cooperation

PRINCIPLES

The Ministers of Health and the Environment recognize that human health, ecosystem health and the economy are interdependent. We believe that:

- all Canadians must have the opportunity to live, work and play in environments that are in harmony with nature;
- ecosystem health is essential to the health of all life forms on Earth;
- development occurring today must not prevent current and future generations from pursuing their own development and meeting their environmental needs;
- where there is a risk of serious or irreversible damage, lack of scientific certainty should not be invoked as a reason to postpone the implementation of effective measures to halt environmental degradation;
- sustainable development needs to be better understood at the scientific level, which implies sharing knowledge and adopting innovative technologies;
- preventive measures are preferable to corrective ones;
- the Canadian population needs to be better informed to make decisions that promote and maintain human and ecosystem health.

Canadians have a responsibility to make decisions that promote human and ecosystem health. The Canadian government must ensure that its own decisions protect the health of the population and the environment, creating conditions that encourage individuals and communities to adopt practices that are consistent with the principles of sustainable development.

AREAS OF COOPERATION

In witness whereof the various governments commit themselves, in the interest of present and future generations of Canadians, to do their utmost to:

- expand knowledge and exchange information on human health, ecosystem health and the determining factors of each;
- identify priority areas requiring Canada-wide action;
- support cooperation between departments and ministries of Health and the Environment and other departments and ministries which have a role to play;
- develop interdisciplinary strategies to promote human and ecosystem health;
- strengthen links between governmental and non-governmental organizations;
- facilitate and promote public awareness programs and public participation.

Source: CCME, November 1996

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Volume 2
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BIBLIOGRAPHY

ACEE, 1998, CD-ROM ET SITES INTERNET.

ASSOCIATION CANADIENNE DE SANTÉ PUBLIQUE (ACSP), 1997. INCIDENCE DES CONDITIONS ET DES POLITIQUES SOCIO-ÉCONOMIQUES SUR LA SANTÉ, OTTAWA, 44 P.

BAKER, F. RISK COMMUNICATION ABOUT ENVIRONMENTAL HAZARDS, *JOURNAL OF PUBLIC HEALTH POLICY*, VOL. 11, Nº 3, 1990, P. 341-359.

BONHOMME, J. P. *POUR PROTÉGER LEUR SANTÉ, LES CITOYENS DOIVENT CONNAÎTRE L'INDUSTRIE CHIMIQUE*, LA PRESSE, MONTRÉAL, 17 MAI 1991, P. C-20.

BOULDING, K., 1966. THE ECONOMICS OF THE COMING SPACESHIP EARTH. IN: ENVIRONMENTAL QUALITY IN A GROWING ECONOMY, NEW YORK, HARPES AND ROW, P. 3-15.

CALDWELL, J.C., 198. ROUTES TO LOW MORTALITY IN POOR COUNTRIES POPULATION AND DEVELOPMENT REVIEW, 12: 171-220.

CANTER, L.W., 1998, METHODS FOR EFECTIVE EIA PRACTICE, CHAP. 6 IN ENVIRONMENTAL METHJODS REVIEW: RETOOLING IMPACT ASSESSMENT FOR THE NEW CENTURY, PORTER A.L. & J.J. FITTAPALDI (EDS), FARGO, USA, AEPI AND 1A1A, P. 58-68

CARDINAL, L., P. GOSSELIN ET A. NANTEL, 1989. L'ANALYSE DES RISQUES SOCIO-SANITAIRES D'ORIGINE ENVIRONNEMENTALE, ÉTAT DE SITUATION ET RECOMMANDATIONS. DOCUMENT DE TRAVAIL, 83 P.

CARRIER, G. ET COLL. *ANALYSE DES IMPACTS DES ÉMISSIONS DE POLLUANTS PRODUITS PAR L'INCINÉRATEUR DES CARRIÈRES DANS L'AIR AMBIANT SUR LA SANTÉ DE LA POPULATION*, DSC MAISONNEUVE-ROSEMONT, MONTRÉAL, 1991, 48 P.

CAVINS, J., 1997. DEFINING GOALS AND CONDITIONS FOR A SUSTAINABLE WORLD, ENVIR. HEALTH PERSPECT. 105: 1164-1170.

CHESS, C. ET COLL. *IMPROVING DIALOGUE WITH COMMUNITIES: A SHORT GUIDE FOR GOVERNMENT RISK COMMUNICATION*, ENVIRONMENTAL COMMUNICATION RESEARCH PROGRAM, NEW-BRUNSWICK, NJ, 1988, 30 P.

COMITÉ DE SANTÉ ENVIRONNEMENTALE DU QUÉBEC (CSEQ), 1998, RAPPORT ANNUEL D'ACTIVITÉS 1997-98, QUÉBEC, HTTP://WWW.CSPQ.QC.CA/CSE

COMITÉ DE SANTÉ ENVIRONNEMENTALE DU QUÉBEC, 1993. ÉVALUATION DES IMPACTS DES GRANDS PROJETS SUR LA SANTÉ. CAHIER D'INTRODUCTION À L'ÉVALUATION DES IMPACTS SUR LA SANTÉ.

COMMISSION MONDIALE SUR L'ENVIRONNEMENT ET LE DÉVELOPPEMENT, 1988. NOTRE AVENIR À TOUS. LES ÉDITIONS DU FLEUVE ET LES PUBLICATIONS DU QUÉBEC, MONTRÉAL.

COMMISSION ON RESOURCES AND ENVIRONMENT, 1994. FINDING COMMON GROUND: A SHARED VISION FOR LAND USE IN BRITISH COLUMBIA. BRITISH COLUMBIA, 98 P.

CONSEIL CANADIENDESMINISTRESDEL 'ENVIRONNEMENT(CCME), 1993, REGARDSURL 'ENVIRONNEMENT 1993, P. 21

CONSEIL CANADIEN DES MINISTRES DE L'ENVIRONNEMENT (CCME), 1993. REGARD SUR L'ENVIRONNEMENT 1993, CCME-SPC-74F, 115 P. ET ANNEXES.

CONSEIL CANADIEN DES MINISTRES DE L'ENVIRONNEMENT, 1996. PROTOCOLE D'ÉLABORATION DE RECOMMANDATIONS POUR LA QUALITÉ DES SOLS EN FONCTION DE L'ENVIRONNEMENT ET DE LA SANTÉ HUMAINE. CCME, PROGRAMME NATIONAL D'ASSAINISSEMENT DES LIEUX CONTAMINÉS, 186 P.

COSTANZA, R. *ET AL.*, 1987. THE VALUE OF THE WORLD'S ECOSYSTEM SERVICES AND NATURAL CAPITAL, NATURE, VOL. 387, 15 MAY, PP. 253-260.

COVELLO, V. T. TRUST & CREDIBILITY IN RISK COMMUNICATION, *HEALTH & ENVIRONMENT DIGEST,* VOL. 6, Nº 1, APRIL 1992, 8 P.

COVELLO, V. T. ET COLL. *RISK COMMUNICATION, RISK STATISTICS AND RISK COMPARISONS: A MANUAL FOR PLANT MANAGERS*, CHEMICAL MANUFACTURERS ASSOCIATION, WASHINGTON, D.C., 1988, 47 P.

DALY, H., 1990. SUSTAINABLE DEVELOPMENT: FROM CONCEPT AND THEORY TOWARDS OPERATIONAL PRINCIPLES. BANQUE MONDIALE, WASHINGTON.

DAVIS K. ET B. SADLER, 1997, ÉVALUATION ENVIRONNEMENTALE ET SANTÉ HUMAINE : PERSPECTIVES, APPROCHES ET ORIENTATIONS, SANTÉ CANADA ET IAIA, 54 P.

EL SERAFY 1991, 1993

EPA CALIFORNIE, 1996. A REVIEW OF THE CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY'S RISK ASSESSMENT PRACTICES, POLICIES, AND GUIDELINES. REPORT OF THERISK ASSESSMENT ADVISORY COMITTEE, CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY.

EPA. *SEVEN CARDINAL RULES OF RISK COMMUNICATION*, APRIL 1988, PAMPHLET.

EUROPEAN ENVIRONMENT AGENCY(EEA), 1995, INTEGRATED ENVIRONMENTAL ASSESSMENT OF ECONOMIC SECTORS AND ACTIVITIES, A SCOPING STUDY, D. BRIGGS ET AL. (EDS), U. OF HUDDERSHFIELD, CHAP. 3, 116 P., PROJECT N° EEA/059/95.

EVANS, R.G. ET G.L. STODDARD, 1994, PRODUCING HEALTH, CONSUMING HEALTH CARE, CHAP. 2, P. 27, IN EVANS ET AL., WHY ARE SOME PEOPLE HEALTHY AND OTHERS NOT?, ALDINE DE GRUYTER, NEW YORK.

EVANS, R.G., BARER, B.L. AND T.R. MARMOR, 1994. WHY ARE SOME PEOPLE HEALTHY AND OTHERS NOT? THE DETERMINANTS OF HEALTH POPULATIONS, ALDINE DE GRUYTER, NEW YORK, 378 P.

FISCHOFF, B., BOSTROM, A., QUADREL, M. J. *RISK PERCEPTION AND COMMUNICATION*, ANN. REV. PUBL. HEALTH, 1993, 14 : 183-203.

GIROULT, E., 1988, WHO INTEREST IN ENVIRONMENTAL HEALTH IMPACT ASSESSMENT, IN ENVIRONMENTAL HEALTH IMPACT ASSESSMENT, UNWIN HYMAN, LONDON.

GOLDBERG, G. IN THE FACE OF FEAR, *OCCUPATIONAL HEALTH AND SAFETY*, MARCH/APRIL 1992, P. 34-46.

GOODLAND R., H. DALY, ENVIRONMENTAL SUSTAINABILITY, CHAP. 14 IN ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT, ED. BY F. VANCLAY AND D.A. BRONSTEIN, OP.CIT.

GOODLAND, R. AND H. DALY, 1995. ENVIRONMENTAL SUSTAINABILITY, CHAP. 14 IN F. VANCLAY AND D.A. BRONSTEIN (EDS), ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT, WILEY, REXDALE, ONTARIO, PP. 303-322.

GOSSELIN, P., BÉLANGER, D., BIBEAULT, J.-F. AND A WEBSTER, 1991. FEASIBILITY STUDY ON THE DEVELOPMENT INDICATORS FOR A SUSTAINABLE SOCIETY. QUÉBEC. FINAL REPORT TO HEALTH AND WELFARE CANADA.

GOSSELIN, P., D. BÉLANGER, J.-F. BIBAULT ET A. WEBSTER, 1991, FEASIBILITY STUDY ON THE DEVELOPMENT OF INDICATORS FOR A SUSTAINABLE SOCIETY, OTTAWA, HEALTH AND WELFARE CANADA.

GOUVERNEMENT DU CANADA, 1992, NORTH AMERICAN FREE TRADE AGREEMENT: CANADIAN ENVIRONMENTAL REVIEW, 121 P., CAT. N^{o} E 74-54/1992^{E}.

GRONDIN, J., PROULX, J.-F., BRUNEAU, S. ET DEWAILLY, E., 1994, SANTÉ PUBLIQUE ET ENVIRONNEMENT AU NUNAVIK, ÉTUDES/INUIT/STUDIES, 18 (1-2) : 225-251

HICKS' (1946)

HILL, H.E., C.L. SEYFRIT, M.J.E. DANNER, 1998, OIL DEVELOPMENT AND SOCIAL CHANGE IN THE SHETLAND ISLANDS 1971-1991, IMPACT ASSESSMENT AND PROJECT APPRAISAL, VOL. 16 (1), MARCH, P. 15-26

HODGE, T., HOLTZ, S., SMITH, C. ET H. BAXTER (EDS), 1995. LES SENTIERS DE LA VIABILITÉ: MESURER LES PROGRÈS, OTTAWA, TABLE RONDE NATIONALE SUR L'ENVIRONNEMENT ET L'ÉCONOMIE.

IAIA, 1996, ACTES, COLL. RANCO

IAIA, 1997, ACTES, COLL. IAIA

KAPLAN GA, HAAN MN. IS THERE A RÔLE FOR PREVENTION AMONG THE ELDERLY? EPIDEMIOLOGIC EVIDENCE FROM THE ALAMEDA COUNTY STUDY. IN : ORY MG, BOND K, EDS. AGING AND HEALTH CARE: SOCIAL SCIENCE AND POLICY PERSPECTIVES. LONDON . ROUTLEDGE, 1989: 27-51

KONHEIM, C. S. RISK COMMUNICATION IN THE REAL WORLD IN *RISK ANALYSIS*, VOL. 8, N^{o} 3, 1988, P. 367-

378.

KOSOSKI, J. *PROVISION OF INFORMATION TO THE PUBLIC: REVISED DISCUSSION DOCUMENT*, OECD ENVIRONMENT MONOGRAPHS, Nº 29, 1990, P. 19-50.

KREWSKI, D. *CURRENT ISSUES IN RISK MANAGEMENT, RISK COMMUNICATION, RISK PERCEPTION AND PHARMACOKINETICS*, DISCUSSION PAPER FOR THE FEDERAL PROVINCIAL ADVISORY COMMITTEE ON ENVIRONMENTAL AND OCCUPATIONAL HEALTH, HEALTH PROTECTION BRANCH, HEALTH AND WELFARE CANADA, OCTOBER 1989, 30 P.

LAINESSE, P. *STRATÉGIE DE COMMUNICATION EU ÉGARD AUX RISQUES À LA SANTÉ PUBLIQUE*, DOCUMENT DE TRAVAIL PRÉPARÉ POUR LE COMITÉ DE SANTÉ ENVIRONNEMENTALE (CSE) TRAITANT DE L'ÉVALUATION DES IMPACTS SUR LA SANTÉ DES GRANDS PROJETS INDUSTRIELS, DSC HÔTEL-DIEU DE LÉVIS, JANVIER 1992, 14 P.

LEON, D.A., CHENET, L., SHKOLNIKOV, V.M. *ET AL.*, 1997. HUGE VARIATION IN RUSSIAN MORTALITY RATES 1984-1994: ARTIFACT OR ALCOHOL OR WHAT? LANCET, 350: 383-388.

LEWIS, C.,1998, COMMUNICATION PERSONNELLE, CONSULTANT POUR B.C. MINISTRY OF HEALTH

LYNCH, J.W., KAPLAN, G.A., AND S.J., SHEMO, 1997. CUMULATIVE IMPACT OF SUSTAINED ECONOMIC HARDSHIP ON PHYSICAL, COGNITIVE. PSYCHOLOGICAL AND SOCIAL FUNCTIONING, NEJM, VOL. 337, Nº 26, DEC. 25, 1997, PP. 1889-1895.

MARMOT, M.G., AND T. THEORELL, 1988. SOCIAL CLASS AND CARDIOVASCULAR DISEASE: THE CONTRIBUTION OF WORK. INTERNATIONAL JOURNAL OF HEALTH SERVICES,18: 659-74.

MEF, 1992, DOCUMENTS À L'APPUI... (EAU)

MEF, 1998, DIRECTIVE POUR LA RÉALISATION D'UNE ÉTUDE D'IMPACT SUR L'ENVIRONNEMENT D'UN PROJET DE LIGNE D'ÉNERGIE ÉLECTRIQUE À HAUTE TENSION, MAI 1998, QUÉBEC, 26 P. SITE INTERNET (FRANÇAIS ET ANGLAIS) : HTTP://WWW.MEF.GOUV.QC.CA. DISPONIBLE GRATUITEMENT.

MINISTÈRE DE L'ENVIRONNEMENT ET DE LA FAUNE DU QUÉBEC (MEF), 1997-1998.

MINISTÈRE DE LA SANTÉ ET DES SERVICES SOCIAUX DU QUÉBEC (MSSS), 1998, TABAC.

MINISTÈRE DE LA SANTÉ ET DES SERVICES SOCIAUX ET MINISTÈRE DE L'ENVIRONNEMENT DU QUÉBEC. *ENTENTE ENTRE LE MINISTÈRE DE LA SANTÉ ET DES SERVICES SOCIAUX ET LE MINISTÈRE DE L'ENVIRONNEMENT RELATIVE AUX INTERACTIONS ENTRE LA SANTÉ ET L'ENVIRONNEMENT*, AVRIL 1987, 4 P. ET ANNEXE.

MINISTÈRE DE LA SANTÉ ET DES SERVICES SOCIAUX. *PROTOCOLE D'ENTENTE ENTRE LE MINISTRE DE LA SANTÉ ET DES SERVICES SOCIAUX ET LES DIRECTEURS DE DÉPARTEMENTS DE SANTÉ COMMUNAUTAIRE RELATIVEMENT À L'ÉCHANGE D'INFORMATION ET AU PROCESSUS DE COMMUNICATION EN MATIÈRE DE PROTECTION DE LA SANTÉ PUBLIQUE*, QUÉBEC, MAI 1991, 13 P.

MSSS, 1998, ÉTUDE D'IMPACT DE LA LOI ANTI-TABAC.

MSSS-MEF, 1987, 1992 ENTENTE...

MURRAY, V. TCHERNOBYL, LE TERRIBLE MENSONGE, *L'ACTUALITÉ*, 1ER JUILLET 1990, P. 20-25.

NOTZON, F.C., KOMAROV, Y.M., ERMAKOV, S.P. *ET AL.*, 1998 CAUSES OF DECLINING LIFE EXPECTANCY IN RUSSIA, JAMA, 279;793-800

NRC, 1983, TRADUIT DANS CSE. 1993

NRC, 1994. SCIENCE AND JUDGMENT IN RISK ASSESSMENT. COMMITEE ON RISK CHARACTERIZATION. NATIONAL ACADEMY PRESS. COMMITTEE ON RISK ASSESSMENT OF HAZARDOUS AIR POLLUTANTS. COMMISSION ON LIFE SCIENCES.

OCDE, 1997, GUIDER LA TRANSITION VERS LE DÉVELOPPEMENT DURABLE : UN RÔLE ESSENTIEL POUR L'OCDE, RAPPORT, NOV. 1997, HTTP://WWW.OECD.ORG/...

OMS, 1947, CONSTITUTION DE L'ORGANISATION MONDIALE DE LA SANTÉ, VOL. 1, NO. 29.

PARÉ, L. *ESTIMATION DES RISQUES ET BÉNÉFICES DE LA CONSOMMATION DES PRODUITS DE LA MER PAR LA POPULATION DE LA BASSE-CÔTE-NORD DU GOLFE SAINT-LAURENT, STRATÉGIE DE COMMUNICATION*, RAPPORT DE STAGE, DSC DE LA CÔTE-NORD (CRSSS-09) ET DSC CHUL, 26 AOÛT 1991, 82 P.

PATE RR, PRATT M, BLAIR SN, ET AL. PHYSICAL ACTIVITY AND PUBLIC HEALTH. A RECOMMENDATION FROM THE CENTERS FOR DISEASE CONTROL AND PREVENTION AND THE AMERICAN COLLEGE OF SPORTS MEDICINE. JAMA, 1995; 273 : 402-7

PEAT MARWICK STEVENSON ET KELLOGG, 1993. REGARD SUR L'ENVIRONNEMENT 1993; ÉVALUATION DES PROGRÈS ACCOMPLIS EN MATIÈRE DE DÉVELOPPEMENT DURABLE. DOCUMENT PRÉPARÉ POUR LE CONSEIL CANADIEN DES MINISTRES DE L'ENVIRONNEMENT. 115 P. + ANNEXES.

PRESIDENTIAL/CONGRESSIONAL COMMISSION ON RISK ASSESSSMENT AND RISK MANAGEMENT, 1997A; 1997B

PUBLIC HEALTH COMMISSION (PHC), 1995, A GUIDE TO HEALTH IMPACT ASSESSMENT, GUIDELINES FOR PUBLIC HEALTH SERVICES, RESOURCE MANAGEMENT AGENCIES AND CONSENT APPLICANTS, MINISTRY OF HEALTH OF NEW ZEALAND, WELLINGTON, 43 P.

RICHER, N. *L'EXPRESSION DU RISQUE TOXICOLOGIQUE*, DOCUMENT DE TRAVAIL PRÉPARÉ POUR LE COMITÉ DE SANTÉ ENVIRONNEMENTALE(CSE) TRAITANT DE L'ÉVALUATION DES IMPACTS SUR LA SANTÉ DES GRANDS PROJETS INDUSTRIELS, DSC HÔPITAL SACRÉ-COEUR DE MONTRÉAL, MAI 1991, 5 P.

SADLER, B. ET AL., 1996, ÉTUDE INTERNATIONALE SUR L'EFFICACITÉ DE L'ÉVALUATION ENVIRONNEMENTALE, RAPPORT FINAL, IAIA ET AGENCE CANADIENNE D'ÉVALUATION ENVIRONNEMENTALE, OTTAWA, NO. CAT. EN 106-37/1996F.

SANTÉ CANADA (1997). L'ENVIRONNEMENT ET LA SANTÉ, PARTENAIRES POUR LA VIE. SANTÉ CANADA, P. 35-51.

SANTÉ CANADA, 1996, LE RÔLE DES PROFESSIONNELS DE LA SANTÉ

SANTÉ CANADA, 1997, GUIDE CANADIEN D'ÉVALUATION DES INCIDENCES SUR LA SANTÉ, VOLUME 1, VERSION PROVISOIRE, MAI 1997.

SANTÉ CANADA, 1997. POUR UNE SANTÉ DURABLE : STRATÉGIE DE DÉVELOPPEMENT DURABLE DE SANTÉ CANADA, OTTAWA, PAGINATION MULTIPLE.

SERAGELDIN, 1993A

SLOOFF, R., 1995, CONSULTANT'S REPORT ON THE COMMONWEALTH SECRETARIAT EXPERT GROUP MEETING ON HEALTH ASSESSMENT AS PART OF ENVIRONMENTAL ASSESSMENT, (ABERDEEM, SCOTLAND, FÉV. 1995), LONDON.

THÉRIVEL, RIKI AND MARIA PARTIDARIO, 1996, THE PRACTICE OF STRATEGIC ENVIRONMENTAL ASSESSMENT, EARTHSCAN, LONDON, CHAP. 2.

UNDP, 1997.

VANCLAY, F. ET D. BRONSTEIN, ÉD., 1995, ENVIRONMENT AND SOCIAL IMPACT ASSESSMENTS, LONDON, WILEY.

VROM (MINISTRY OF HOUSING, PHYSICAL PLANNING AND ENVIRONMENT), 1989, DUTCH NATIONAL ENVIRONMENTAL POLICY, PREMISES FOR RISK MANAGEMENT, SECOND CHAMBER OF THE STATES GENERAL, SESSION 1988-89, 21137, N° 5, 29 P.

WILKINSON, R.G., 1989. CLASS MORTALITY DIFFERENTIALS, INCOME DISTRIBUTION AND TRENDS IN POVERTY 1921-1981. JOURNAL OF SOCIAL POLICY 18 : 307-35.

WILKINSON, R.G., 1992. INCOME DISTRIBUTION AND LIFE EXPECTANCY. BRITISH MEDICAL JOURNAL, 304 : 165-68

CALOW, P. (ED.), 1998, HANDBOOK OF ENVIRONMENTAL RISK ASSESSMENT AND MANAGEMENT, BLACKWELL SCIENCE, OXFORD.

TRANSFERT ENVIRONNEMENT, 1996. PARAMÈTRES SOCIAUX DE LA GESTION INTÉGRÉE DES DÉCHETS, RAPPORT FINAL PRÉSENTÉ À RECYC-QUÉBEC, 95 P. ET ANNEXES, SOUS LA DIRECTION DE A. DELISLE.

ENVIRONMENTAL PROTECTION AGENCY (EPA), 1988, SEVEN CARDINAL RULES OF COMMUNICATION, PAMPHLET.

PUBLIC AND ENVIRONMENTAL HEALTH BRANCH (PEHB), 1997, HEALTH IMPACT ASSESSMENT GUIDELINES, DPT OF COMMUNITY AND HEALTH SERVICES, HOBART, TASMARNIA, AUSTRALIA, DRAFT FEBRUARY 20, 1997.

ORGANISATION DE COOPÉRATION ET DE DÉVELOPPEMENT ÉCONOMIQUE (OCDE), 1996. LA COHÉRENCE DANS L'ÉVALUATION ENVIRONNEMENTALE, PARIS, 112 P.

PUTNAM, R.D. (1993) MAKING DEMOCRACY WORK: CIVIC TRADITIONS IN MODERN ITALY, PRINCETON: PRINCETON UNIVERSITY PRESS.

APPENDIX I

EXAMPLES OF HEALTH RISKS BY ECONOMIC SECTOR

EXAMPLES OF HEALTH RISKS BY ECONOMIC SECTOR

One of the key roles performed by public health practitioners involved in EA is to clearly identify possible adverse impacts of contaminants and irritants, as well as other social and economic aspects of projects, programs and policies. Once identified, these impacts can be eliminated or minimized. Residual impacts can be addressed through mitigation or compensation measures, and balanced with the benefits of a project to determine whether the undertaking is acceptable from a public health perspective (see Chapter 6).

In this section we will limit ourselves to examining adverse impacts which are frequently encountered with certain kinds of projects. First, a summary of the general context for each type of project is presented, followed by a standard table which summarizes the potential impacts most frequently encountered.

The grid used here enables health professionals who are unfamiliar with a project to quickly develop a solid understanding of potential impacts. The grid can also serve as a checklist, in the sense that the impact study should provide enough information to fill out every cell. This type of grid can also be useful in the initial stage of a guideline: the public health worker should request that the impact study provide data on all environmental stressors which warrant documentation. Finally, a grid can also be a useful memory aid when drafting guidelines for conducting an impact study.

The examples presented below were selected from among cases recently examined by the implementation team for this Handbook. One of the team's ultimate goals is to expand the range of cases presented here through a Canada-wide collaborative effort.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 3 of 11

Energy

Canadian outlook

Like most industrialized countries, Canada's energy consumption is high; this is compounded by its northern location. On a *per capita* basis, only the United States has a higher consumption rate than Canada. Overall energy use rose markedly from 1960 to 1973, the year oil prices increased significantly. There was a drop in global energy consumption after 1973 and again during the economic recession in the early 1980s.

Canadian energy consumption in 1994 was approximately 8,000 petajoules, or 8.0 x 10^{18} joules, corresponding to about 175 million ton oil equivalents (TOE)[1]. The highest energy demand in 1994 was for oil, which represented 37% of consumed energy as compared to 56% in 1971. Natural gas was next at 27% of energy used (19% in 1971). Electric power[2] provided 21% of energy in 1994 as compared to 9% in 1970, while 10% came from coal and 5% from wood (12% and 7% respectively in 1970). The use of oil has therefore decreased 33% in 24 years to the benefit of natural gas, hydroelectric and nuclear power. Finally, it should be mentioned that energy resources and production play a crucial role in Canada's economy, accounting for nearly 8% of the GDP.

Various forecasting models predict a 9,000 to 10,000 petajoule energy demand in 2010. This means that growth will be much slower between 1995 and 2010 than it was over the past three decades. Moreover, these forecasting models indicate that the share of each of these energy sources is stabilizing. Oil will therefore continue to play an important role, while new energy sources (solar, biomass and wind power, etc.) are not expected to make significant inroads.

Energy use in Quebec

From 1961 to 1997, total energy consumption in Quebec rose from approximately 17 million ton oil equivalents (TOE)[3] to nearly 34 million TOE in 1995, a 100% increase in 35 years. But this growth was not distributed evenly. The strongest growth period was recorded during the 13 years between 1961 and 1974 when consumption reached approximately 32 million TOE in 1974, meaning the annual growth rate was 7%. Growth was irregular after the oil crisis in 1973, and the economic recession in the early 1980s caused a marked decline in energy use in Quebec. A more normal growth rate of just over 2% per annum ensued, leading the ministère des Ressources naturelles du Québec (MRN) to predict that this rate will be stable until 2011 when a little over 45 million TOE will be used.

The dominant form of energy in Quebec in 1971 was oil. It represented 74% of demand, followed by electricity (19%) and gas (5%). By 1995, this situation altered dramatically: oil represented only 41.5% of Quebec's energy balance, followed very closely by electricity at 41.3%. The use of natural gas surged upwards from 5% in 1971 to 16% in 1995. According to MRN predictions, the use of electricity and natural gas should rise slightly between now and 2011 while oil dips to 34.5%. No major upheavals are expected to alter Quebec's energy picture the way the oil crisis did in 1973.

Primarily because of the transportation sector, oil should still represent at least a third of the province's energy consumption between now and the end of the 21st century. Looking at consumption changes by sector, we see that oil accounted for 82% of home heating in 1971 and only 19% in 1995. Electricity, on the other hand, increased from 7% usage for domestic heating in 1971 to nearly 71% in 1995. It is important to specify that even though the use of non-traditional energy sources (wind and solar power, burning forest biomass and urban waste, etc.) rose 160% between 1975 and 1995, their contribution to Quebec's energy use is limited to four million TOE in 1995, or 11% of total consumption.

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[1] One TOE equals the amount of energy contained in a barrel of Canadian crude oil.

[2] Includes hydroelectric power and electricity generated by nuclear or natural gas or coal-fired power stations.

[3] One TOE equals approximately 11 kWh (kilowatt hour).

It is also noteworthy that energy conservation has helped reduce Quebec's energy demand. Excluding energy used in transportation, the average household energy consumption of approximately 2.65 TOE in 1984 declined to 2.51 TOE in 1994. This was one of the lowest rates in Canada, compared to Manitoba (4.0 TOE), Ontario (3.55 TOE), New Brunswick (2.9 TOE) and British Columbia (2.68 TOE).

In completing this outline, it must be said that the MRN feels that the use of non-traditional energy sources (wind and solar power, etc.) will fall from 9.6% of the Quebec energy balance in 1994 to 8.4% in 2011. Although it was predicted in the 1980s that these energy sources would become substitutes, technological hurdles and development costs have hindered their success.

References

Canada (1996) *The State of Canada's Environment.* Government of Canada, Ottawa, 820p.

MER (1992) *L'énergie au Québec*, 1992 edition. Ministère de l'Énergie et des Ressources, Government of Quebec, 106p.

MRN (1997) *L'énergie au service du Québec.* Ministère des Ressources Naturelles, Government of Quebec, 108p.

MER (1997) *L'énergie au Québec, 1997 edition.* Ministère de l'Énergie et des Ressources, Government of Quebec, 120p.

NEB (1991) *Canadian Energy Supply and Demand 1990-2010,* Summary Report. National Energy Board, Government of Canada, 20p.

NEB (1994) *Canadian Energy Supply and Demand, Trends and Issues.* National Energy Board, Government of Canada, 76p.

NRCan (1993) *Canadian Energy Outlook, 1922-2020.* Natural Resources Canada, Government of Canada, 99p.

Hydroelectric dams

Extent of Quebec's production

Although there are some hydroelectric power stations in a few Canadian provinces, Quebec's development of its vast, harnessable hydraulic resources has resulted in the majority of this production being concentrated in Quebec since the early 1950s. The growth in the use of this form of energy obviously accompanied this development. In fact, if the transportation sector is excluded, electricity now meets most of the energy requirements of people and business, holding a 50% to 65% share of the markets involved.

Quebec is currently the world's third-ranking hydroelectric producer, with a power base of nearly 40,000 megawatts (MW), including the energy from Churchill Falls in Newfoundland's Labrador territory. Three-quarters of this power belongs to Hydro-Québec, which has built 83 power stations in the territory. Churchill Falls accounts for 12% of the total and private producers for just over 8%. With its total power of just over 15,000 MW, the La Grande complex is currently the world's leading hydroelectric installation.

Change in demand

The Quebec government wishes to continue harnessing various rivers and increasing power not only to meet the predicted Quebec demand, but also for export markets. Hydro-Québec's demand predictions are usually based on demographic, economic and energy outlooks. However, electricity demand forecasts made in the early 1990s have recently been revised downwards. The initial expected annual growth rate of 2.2% is now 1.5%, or half that of the period between 1980-1995 and only a quarter of that of the previous fifteen years.

The downward revision of the annual growth rate in electricity demand was one of the primary reasons for suspending the work scheduled for the 1990s on the Grande Baleine complex. Nevertheless, some medium-size projects have been started recently, such as the facility at the Sainte-Marguerite-3 River north of Sept-îles (nearly 900 MW). Moreover, the Quebec government has made it possible for private concerns to produce electricity and sell it to Hydro-Québec. These projects are normally new power stations but some stations abandoned several years ago are being refitted, such as those on the Chaudière River and at Sept-Chutes on the Ste-Anne River near Québec. These hydroelectric plants, however, must produce less than 50 MW of power, since Hydro-Québec remains the only company with authorization to manage projects with a greater output.

Socio-economic impacts

Because building a hydroelectric power station requires creating a reservoir behind a retaining structure (dam) made of rock fill (fill dam) or concrete, its location may result in significant socio-economic and environmental repercussions. For example, the installation of the La Grande complex in northern Quebec upset the traditional lifestyle of several Aboriginal groups.

Atmospheric impacts

Hydroelectricity is usually described as clean energy, since it is not produced from fossil fuels that emit gaseous atmospheric pollutants. Nevertheless, the construction of dams has led to questions about their contribution to the greenhouse effect. Tree loss in flooded areas could exacerbate the greenhouse effect because of vegetation decomposition (CO_2 and CH_4 emissions) and the loss of the carbon sink, since tree growth absorbs CO_2. However, the models used indicate a very low environmental impact in terms of greenhouse gases.

Terrestrial impacts

From an environmental perspective, priming a reservoir first causes the disappearance of terrestrial fauna habitats by destroying plant resources. Shoreline vegetation is most affected and for many years after an artificial reservoir is filled, the new banks often remain barren of this type of plant life because of the marling[4], which can be quite significant. Because of their limited ability to migrate, the smaller fauna are the most affected by the introduction of a new dam.

Aquatic impacts

The aquatic environment is subject to the greatest upheaval in the first few years following the priming of a reservoir. What was once a river becomes a lacustral environment in which the physical and chemical parameters are greatly altered. Submerging the vegetation produces large concentrations of organic material, which is broken down by microorganisms. There is an increase in the biochemical oxygen demand (BOD) accompanied by a reduction in dissolved oxygen concentration. At the same time, nutrient elements (nitrogen and phosphorus) released by the decomposition of this organic material foster the growth of phytoplankton. This is usually accompanied by an observable change in the composition of the ichthyological community. Some species of fish flourish while others diminish.

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[4] Marling is the variation in the reservoir's water level caused by periods of dry or rainy weather.

Mercury

One major problem caused by flooding the terrestrial environment is the transformation of inorganic mercury bound to the rocky subsoil into organic mercury (primarily methyl mercury), which can be biologically accumulated by aquatic organisms. The presence of water encourages the microbial activity producing this transformation. Since the mercury concentration in contaminated aquatic fauna is five to six times too high, restricted fish consumption represents a significant socio-economic repercussion for local human communities.

The level of fish flesh contamination varies with the species, but in all cases it is a gradual process, occurring over several years. In the La Grande 2 reservoir, for example, mercury concentration in flesh of the Northern sucker and lake whitefish reached 0.5 mg/kg by the fifth year after the reservoir was primed, and stabilized there until at least the ninth year. In the case of the carnivorous pike and northern pickerel, the concentration increased steadily until at least the ninth year when it reached 3 mg/kg. Since studies on the subject do not agree, it is difficult to predict how long mercury concentrations in fish will remain higher than normal, but a minimum of 15 to 30 years is considered realistic.

This situation obviously has repercussions on how Aboriginal communities who normally eat the fish will feed themselves. In its "Health Effects Assessment Summary Tables" (HEAST), the EPA states that the daily ingested dose of mercury should not exceed 0.002 mg/kg/d. Health Canada has established that fish for consumption should not contain more than 0.5 mg of mercury per kg. Given the level of contamination in Quebec fish, it is estimated that people should eat no more than eight meals (230 grams of fresh fish) per month of the insectivorous species and no more than two meals per month of the more contaminated fish-eating species. It must be said, however, that because of their traditional lifestyle, which includes eating large quantities of fish, these rules are not necessarily followed by the Aboriginal populations inhabiting Quebec's northern regions. These people are therefore likely to bioaccumulate higher levels of mercury than are populations who consume less fish.

Impacts downstream from the reservoir structure

There may be major repercussions downstream from the dam because of reduced water flow, particularly when the reservoir is being filled. The most obvious case is that of the anadromous fish in the area, which cannot swim upriver to spawn. The dam itself is also an insurmountable hurdle for these fish. Depending on its size, it is possible, however, to install a fish-pass to help them swim upriver. Some recreational usages may also be lost as a result of severe reductions in the rate of water flow and breadth of the watercourse, especially in the dam's initial post-construction years.

Construction period

The environmental disturbances occurring during a dam's construction must also be mentioned. Opening new temporary or permanent roads, heavy truck traffic and blasting all produce dust that falls on and pollutes the environment. Add to this the noise pollution and the esthetic degradation of the natural environment. As a secondary impact, the presence of roads leading to the dam may open a previously inaccessible natural environment, resulting in the too-familiar consequences of tourism

activities: destruction of wildlife or waterfowl habitats, over-usage of certain areas, pollution from litter and motor vehicles, wildlife disturbance, etc.

Dam failure

The disaster that is most feared is a catastrophic dam failure, resulting in the rupture of the retaining structure and the sudden, rapid and uncontrolled release of the reservoir water. This would cause a flood wave to swallow the valley downstream from the dam. The worst consequences would be loss of life and major damage downstream from the point of failure.

On a global scale, some 8,000 people have perished as a result of dam failures in the 20th century. In Quebec, dam management is subject to stringent criteria. Prior to the Saguenay floods of 1996, the only incident in which lives were lost was the 1966 failure of the Éboulements reservoir, when three died at St-Joseph-de-la-Rive in the Charlevoix region. Even without loss of life, dam failure can cause significant damage to the natural environment. A 1984 dam failure in the Laurentian Wildlife Reserve north of Québec laid waste to about 144 hectares of forest over a distance of 6 km and carried away more than 2 million m^3 of loose material, destroying one of the reserve's primary wildlife habitats.

The Saguenay incident occurred between July 19 and 21, 1996, when devastatingly high water levels after exceptionally heavy rains caused many rivers to overflow. Public and private property suffered extensive damage. In addition to the devastation of forest and agricultural lands, downtown Chicoutimi and part of the city of La Baie vanished under the rising flood waters. It was during those three days that the dams and levees overflowed and ruptured.

Sector: Energy **Activity: Hydroelectric Dam Structure**[5]

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster	- dam failure	- destruction of terrestrial and aquatic habitats	- downstream from the dam (up to tens of kilometres away)	- regular dam inspection - preparation of evacuation plan	- Bill forthcoming, 1998 (Government of Quebec)
Gaseous or atmospheric emissions	- CO_2 (from the destruction of vegetation)	- greenhouse effect	- global	- none	- Rio (1992) and Kyoto (1997) commitments
Liquid or waterborne emissions	- organic mercury	- contamination of aquatic organisms	- reservoir (upstream	- none	1 µg/L (Q-2, drinking water regulation.) 2 µg/kg/d, HEAST 0.5 mg/kg in flesh[6]
	- decomposing organic material	- water pollution, reduction in dissolved oxygen	- reservoir	- recover vegetation prior to priming reservoir	- none
	- floating debris	- water pollution, insalubrity, esthetics	- reservoir	- recover vegetation prior to priming reservoir	- none
Solid or soil-borne emissions	- varied construction debris (boulders, sand, etc.)	- pollution, insalubrity, esthetics	- construction site vicinity - access roads	- recover waste materials - restore the sites - transplanting	- none
Disamenities	- upstream flooding	- destruction of terrestrial habitats	- reservoir zone	- adjustments	- none
	- downstream drought	- destruction of aquatic habitats (affecting fish)	- downstream riverbed	- adjustments, migration channels (for fish)	- none
	- noise, dust (during construction)	- insalubrity	- construction area		- noise???
Indirect impacts or other exposure	- depreciation - social conflict - exploitation of wildlife or other resources	- heritage, economic or tourist	- dam construction area and access roads	- communication - monetary compensation	

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[5] Applicable to the construction of a concrete or fill dam that creates a reservoir flooding terrestrial habitats.

[6] According to Health Canada, fish for consumption should contain no more than 0.5 mg/kg of mercury.

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biological/ Environmental Monitoring Indicators	Information/ References
Technological disaster	injury, trauma, death	- communities downstream from the dam, particularly those on the banks of harnessed rivers	- very rare	- public safety reports - regular inspections	Boivin *et al* (1994)
Gaseous or atmospheric emissions	- climate changes	- global	- rare (in the case of dams)	- atmospheric CO_2 concentration	- Mysak (1994)
Liquid or waterborne emissions	- poisoning (behavioural and neurological disorders)	- people eating large quantities of fish	- rare to frequent	- Hg levels in blood and hair (15 to 30 mg/kg in hair[7])	Tremblay *et al* (1994), BAPE (1993) and
	- N.A.	- N.A.	- N.A.	- BOD level	Hydro-Québec (1993)
	- insalubrity quality of life	- neighbouring communities, people using the area	- occasional	- visual appearance of the area	BAPE (1993) and Hydro-Québec (1993) MEF and MSSS (1995)
Solid or soil-borne emissions	- N.A.	- N.A.	- N.A.	- N.A.	
Disamenities	- quality of life	- local communities	- occasional to frequent	- complaints/perception	BAPE, Report #60 (1993) Hydro-Québec (1993) Complexe Grande-Baleine, project brief
	- quality of life	- local communities	- occasional to frequent	- complaints/perception	
	- quality of life	- local communities	- rare to occasional	- complaints/perception	
Indirect impacts or other exposure	- quality of life - stress - changes to the Aboriginal diet = ↑ cardiovascular disease, diabetes, etc.	- local and regional communities - Aboriginal communities	- occasional to frequent - occasional to frequent	- complaints/perception - morbidity/mortality indicators	

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[7] This concentration is three times the limit recommended by WHO but has been impossible to apply to Quebec Aboriginal communities for whom fish is the dietary mainstay.

References

BAPE (1993) *Aménagement hydro-électrique Sainte-Marguerite-3*. Bureau d'audiences publiques sur l'environnement, Government of Quebec, Report #60, 452p.

Boivin, R., B. Bouchard, M. Desrochers, L. Molgat, J.-J. Paré, B. Robert and R. Tinawi (1994) *Dam Safety: risks and measures*. Great Whale Environmental Assessment, Background Paper No. 6, Great Whale Public Review Support Office, (Montreal) 49p.

Chamberland, A. and L. Gagnon (1995) *Comparison of atmospheric emissions of energy systems*. Hydro-Québec, 10p.

Hydro-Québec (1993) *Complexe Grande-Baleine, rapport d'avant-projet*. Société Hydro-Québec, 294p. + appended maps.

MEF (1992) *État de l'environnement au Québec, 1992*. Ministère de l'Environnement et de la Faune, Government of Quebec, Les éditions Guérin, 560p.

MEF and MSSS (1995) *Guide de consommation du poisson de pêche sportive en eau douce*. Ministère de l'Environnement, ministère de la Santé et des Services sociaux, Government of Quebec, 132p.

MRN (1997) *L'énergie au service du Québec*. Ministère des Ressources naturelles, Government of Quebec, 108p.

MRN (1997) *L'énergie au Québec, 1997 edition*. Ministère des Ressources naturelles, 120p.

Mysak, L.A. (1994) *Variabilité et changement climatiques et les aménagements hydroélectriques dans le nord du Québec*. Great Whale Environmental Assessment, Background Paper No. 1, Great Whale Public Review Support Office, (Montreal), 98p.

Nicolet, R., L. Roy, R. Arès, J. Dufour, G. Marinier and G. Morin (1997) *Rapport de la Commission scientifique et technique sur la gestion des barrages*. Government of Quebec, various pagings.

Tremblay, A., M. Lucotte and C. Hillaire-Marcel (1994) *Le mercure dans l'environnement et les réservoirs hydroélectriques*. Great Whale Environmental Assessment, Background Paper No. 2, Great Whale Public Review Support Office, (Montreal), 177p.

World Bank (1991) Environmental Assessment Sourcebook. Volume III: Guidelines for environmental assessment of energy and industrial projects. World Bank Technical Paper #154, Washington D.C., 237p.

Cogeneration power stations

Nature of cogeneration

Cogeneration means the simultaneous production of two types of energy, usually electricity and steam. This combined generation of two forms of energy also calls for one or more energy sources. Natural gas is the most commonly used, and the other source (which normally represents less than 10% of the energy contribution) may originate from the combustion of different biomasses, wastes, or even an alternative energy such as wind power. In reality though, most developers have chosen to use declassified oil or grade 2 oil as the alternative fuel.

SUGGESTION TO INSERT AN ILLUSTRATION SHOWING A TYPICAL (GENERIC) SCHEMATIC OF A COGENERATION PLANT

Natural gas and a fossil fuel source are usually used to drive the turbines that power the electricity-producing generators. The hot gases are recovered from the turbines, and in turn drive the steam turbines. The steam can be used by a variety of industrial clients or to drive yet another electricity-producing generator. Each developer has a number of possible combinations to assess, which depend on potential client needs. As a general rule, industrial clients buy the steam and Hydro-Québec buys the electricity.

Atmospheric emissions

Environmental constraints to operating cogeneration plants are essentially atmospheric. Even when the plant uses only natural gas, the full range of primary atmospheric pollutants can be observed: suspended particulates, sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and volatile organic compounds (VOCs). While emissions of these substances are minimal when natural gas is burned, they increase markedly when fossil fuels are used. These pollutants include suspended particulates, several greenhouse gases (CO_2, CH_4 and N_2O), gases that cause acid rain (SO_2 and NO_x) and substances that are irritants or a source of ozone and urban smog (NO_x and VOCs). Burning heavy oil or fossil fuel can also cause the release of polycyclic aromatic hydrocarbons (PAH). Risk calculations in the latter scenario usually predict a 10^{-6} (or, one person per million) increase in the incidence of cancer in adults.

Wastewater

The wastewater discharged into the environment from cogeneration plants usually comes from routine purges of the boilers and residual steam condensers. More wastewater is also generated when machinery or piping is cleaned. As a general rule, this wastewater contains few pollutants, although the presence of some biocides employed to prevent the growth of bacteria in the machinery may give these liquid wastes toxic properties.

Vapour plume

The existence of a vapour plume may cause a variety of problems. For example, if the plume changes into ground-level fog, it can alter visibility, or in winter it can form ice on the road surface. In either case, road safety can be jeopardized.

Odours

Cogeneration power plants should not cause unpleasant odours unless they use large quantities of fossil fuels when the gas system breaks down. In this instance, the presence of NO_x and SO_2 is a potential source of odour.

Economic relevance

The Bureau d'audiences publiques sur l'environnement hearings have indicated that the cogeneration power plant issue was more socio-political than environmental. Many stakeholders actually question the relevance of building such plants when there is an energy glut and incentive to conserve energy.

Socio-economic impacts

If the arrival of a cogeneration plant has the potential to stimulate a sector's economy by creating jobs and increasing patronage of neighbouring businesses, there is nevertheless agreement that negative socio-economic impacts can also result. They can arise from a fear that some form of pollution, or just the presence of the plant, will cause degradation of the natural and human environment, or even a depreciation in the neighbourhood's economic value.

Sector: Energy **Activity: Cogeneration power plant burning primarily natural gas**

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster	fires, explosions	deposits, smoke, destruction	site and perimeter	confinement, capture	CSA Z731-95, emergency measures planning NFTA 850
Gaseous or atmospheric emissions	- suspended particles	- photosynthesis inhibition (deposits on leaves)	- site and perimeter	- dust collector	- 150 $\mu g/m^3$ (24h), Q-2, atm. qual. reg.
	- NO_2	- ground-level smog and ozone formation	- regional	- catalytic reduction	- 0.2 ppm (1 hour) and 0.1 ppm (24h); Q-2, atm. qual. reg.
	- VOC	- ground-level smog and ozone formation	- regional	- recovery (biofiltration)	- none
	- CO_2	- greenhouse effect	- global	- reduce combustion	- Rio (1992) and Kyoto (1997) greenhouse gas commitments
	- CH_4	- greenhouse effect	- global	- none	
	- SO_2	- acid rain, toxic to vegetation	- vicinity and community	- recovery and absorption	- 0.5 ppm (1h) and 0.1 ppm (24h); Q-2, atm. qual. reg.
	- CO	- pollution	- site and perimeter	- recovery and combustion	- 0.3 ppm (1h) and 13 ppm (8h average); Q-2, atm. qual. reg.
	- PAH	- pollution	- site and vicinity	- recovery	- 0.2 $\mu g/m^3$ (8h), total PAH (MUC)[8]
Liquid or waterborne emissions	- suspended materials	- insalubrity and turbidity	- captor watercourses	- holding and sedimentation tank	- 0.5 mg/L (Env. Canada raw water criterion)
	- anti-corrosive substances and biocides in coolant water	- toxicity to aquatic organisms	- captor watercourses	- none	- none
Solid or soil-borne emissions					
Disamenities	- noise and	- salubrity	- vicinity	- absorbent zone, better technology	- L_{eq} 45 dB (night) and 50 dB (day)
	vibrations	- salubrity, visibility, safety	- site and perimeter	- condensation inside stack	- none
	- vapour plume - odours	- salubrity	- vicinity	- filtration	- municipal reg.
Indirect impacts or other exposure	depreciation	economic and social value	perimeter and vicinity	compensation citizen participation	Q-2, section IV

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[8] Standards taken from the Montreal Urban Community air quality regulations.

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biological/ Environmental Monitoring Indicators	Information/ References
Technological disaster	respiratory irritation, burns, death	workers and neighbourhood	very rare	public safety report	CSPQ (1994)
Gaseous or atmospheric emissions	- respiratory tract irritation, asthma	- neighbourhood (asthmatics)	- rare	- epidemiological surveillance of level of atmospheric particles	BAPE (1993a, b) and BAPE (1994) CSPQ (1994) Levallois and Lajoie (1997)
	- respiratory tract irritants	- neighbourhood	- rare	- atmospheric level of NO_2	
	- none at predicted concentrations	- N.A.	- N.A.	- atmospheric emissions tonnage	
	- climate changes	- global	- frequent	- atmospheric emissions tonnage	
	- climate changes	- global	- frequent	- atmospheric emissions tonnage	
	- respiratory problems	- neighbourhood (asthmatics)	- rare	- atmospheric emissions tonnage	
	- ↑ carboxyhemo-globinemia	- neighbourhood	- very rare	- atmospheric and blood CO_2 measurement	
	- cancers (mostly lung and bladder)	- neighbourhood	- very rare	- level of BaP and other ambient air PAH	
Liquid or waterborne emissions	- insalubrity, no direct effect	- users of polluted water (bathers, boaters, etc.)	- rare	- aquatic SPM measurement	BAPE (1993a, b) and BAPE (1994)
	- unknown	- N.A.	- N.A.	- N.A.	
Solid or soil-borne emissions					
Disamenities	- quality of life and sleep, stress	- neighbourhood	- unknown	- complaints, ambient noise measurement	BAPE (1993a, b) and BAPE (1994)
	- quality of life	-neighbourhood	- unknown	- complaints	
	- quality of life	- neighbourhood	- unknown	- complaints	CSPQ (1994)
Indirect impacts or other exposure	- stress, quality of life assessment role	- neighbourhood and community	- unknown	complaints, role of assessment and perception studies	CSPQ (1994)

References

BAPE (1994) *Centrale de cogénération d'énergie à Québec*. Bureau d'audiences publiques sur l'environnement, Government of Quebec, Report #76, 186p.

BAPE (1994) *Centrale de cogénération d'énergie à Montréal-Est*. Bureau d'audiences publiques sur l'environnement, Government of Quebec, Report #79, 119p.

BAPE (1994) *Centrale de cogénération d'énergie à Bécancour*. Bureau d'audiences publiques sur l'environnement, Government of Quebec, Report #81, 123p.

Concord Environmental (1992) *Risk assessment and risk management for a gas turbine cogeneration plant*. Final report CEC J3062, Downsview, Ontario, Canada.

CSPQ (1994) *Projet de cogénération de Québec*. Avis du Centre de santé publique de Québec, 46 p.

Klem, T., J. Grant and C. Casey (1993) "Three workers die in electrical power plant fire", NFTA Alert Bulletin, *NFTA Journal*, March/April 1993, pp. 44-47.

Transport and liquefaction of natural gas

Nature of project

The information used in preparing this grid was taken from the PAC-RIM LNG project submitted to the Government of British Columbia in 1995. The project involves exporting liquid natural gas to Asia using specially designed vessels called LNG tankers.

The project includes three components. The first is the construction of a pipeline (24 to 30 inches in diameter) from Prince George, B.C., to Prince Rupert or Kitimat on the Pacific coast; the pipeline, either 507 kilometres. (Kitimat) or 592 kilometres. (Prince Rupert) in length, would carry 14 million cubic metres (500 million cubic feet) of natural gas per day with a diameter of 24 inches.

The second component is a plant for liquid natural gas (LNG) production. With a production capacity of 3.5 million tons of LNG per year, the plant (in Prince Rupert or Kitimat) would liquefy the gas by cooling it at -160 °C (-260 °F) in a cryogen tower. When liquefied, natural gas is reduced 625 times in volume for transport by an LNG tanker. Transformation involves the removal of carbon dioxide (CO_2) followed by removal of the water contained in the gas. Liquefaction is achieved through cooling with compressed propane gas and a mixture of pressurized nitrogen, methane, ethylene and propane. Refrigeration system operations require 300,000 litres of sea water per minute to cool the compressed gases. After liquefaction, LNG would be stored in four double-walled pressurized reservoirs measuring 95,000 cubic metres (600,000 barrels) each, at a temperature of - 160 °C.

The third component is the construction of a deep water port (Prince Rupert or Kitimat) to transsship LNG in tankers with double-walled pressurized holds and carrying capacities of 125,000 to 135,000 cubic metres. Sixty vessels a year would be loaded with LNG for transport to Asian countries like Korea and Japan.

Pipeline construction was estimated at $575 to $725 million, and plant and port construction at about $850 million. Total costs would be $1.3 to $1.5 billion and would employ 3,000 persons/year. The promoters estimate that the project would add about $12 billion to Canada's gross national product during its useful life, estimated at 20 years.

Environmental impacts

This is a major project in a northern setting with environmental impacts on water and air quality, soil, water fowl, bird life and large mammals (caribou and bears). The living patterns and hunting and trapping zones of the Aboriginal people of the region would be affected. Impacts are described for each of the project components: the pipeline, the factory and the deep-water port.

Impacts resulting from the construction and operation of the pipeline

A pipeline has little impact on air quality unless there is a leak. However, gas pumping stations operating with fossil fuels release low amounts of combustion gases into the atmosphere: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x) and volatile organic compounds (VOC) (see section on the liquefaction plant for the description of the effects of these pollutants).

The 18-metre-wide pipeline right-of-way would impact on vegetation and on aquatic and terrestrial fauna, and would cross about 200 watercourses of varying sizes along with several wetlands. Shoreline destruction and wetland drainage draining on an 18-metre swathe are major disturbances. Suspended solids and petroleum products could be introduced into the water during construction. These disturbances would impact on fish life, especially the five species of salmon found on the West Coast of Canada.

Pipeline construction would also impact on migratory and non-migratory bird life by destroying habitats through forestry and leading to nest abandonment. Ungulates (caribou, moose, deer, etc.) could be disturbed by construction machinery, while the the pipeline could alter the migratory habits of species like the caribou. The habitats of large carnivores (black bears, grizzlies and cougars) could also be disturbed, especially in cases where their food source (like salmon) is affected as well. The corridor defined by the pipeline route could facilitate hunting access and increase those pressures on various species.

The pipeline would run through the lands of various native tribes, and changes on wildlife habitats could have a negative impact on the Amerindians, since several animal species play a major role in their diet. Increased hunting could result in supply problems for Amerindian populations. The promoter's impact study finds that Amerindian quality of life would improve through job creation and economic benefits. However, the negative effects of such a major industrial installation must be factored into the equation.

More direct impacts on the health of native populations could result from food source contamination (plant or animal) through the spillage of petroleum products, or through herbicides used to maintain a free zone in part of the corridor. Changes in diet could also occur through disturbances to the animal resource or increased access to foods brought in from urban regions. Past studies have shown that seemingly minor changes in a traditional diet can lead to a variety of health problems.

Breakages can occur in pipeline transportation, with the potential ignition of escaped gas. Natural gas is highly flammable, and the heat generated by breakages can be enough to start fires. There is a permanent risk of human injury or death in the vicinity of an area where this type of disaster could occur.

Impacts related to the construction and operation of the natural gas liquefaction plant

With an oil or gas complex there is always the possibility of hydrocarbon leaks and explosions. The greatest risk here would be leaked natural gas leak or LNG, which is flammable in the atmosphere at a concentration of 6 to 13%. Depending on the size of the leak and the direction and strength of the wind, the natural gas plume could travel toward inhabited areas in a flammable concentration, with potentially disastrous results.

Several polluting gases would be released into the atmosphere during the plant's operations. Carbon dioxide (CO_2) removal, the use of burners (flare stacks) to dispose of surplus methane or various hydrocarbons and minor leaks from the numerous valves would release carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC) and methane (CH_4).

Carbon monoxide (CO) is an odourless gas that can increase carboxyhemoglobin. Concentrations would not be high enough to be a problem, however, and it is not considered a pollutant here.

Nitrogen oxides (NO_x) include nitric oxide (NO) which transforms rapidly into nitrogen dioxide (NO_2); a brownish gas with a sharp, irritating odour that can oxidize cell membranes. This gas can decrease odour perception, alter pulmonary function and in cases of severe exposure, can lead to pulmonary edema. One of the most significant effects of chronic exposure is emphysema and a reduction in forced expiratory volume. NO_2 reacts with VOCs to form photochemical smog (see below).

Volatile organic compounds (VOCs) are hydrocarbons that evaporate at ambient temperature and exist in vapour form in the atmosphere; they number in the thousands, and some are relatively toxic. The principal VOCs produced by combustion engines are polycyclic aromatic hydrocarbons (PAHs) that form in almost all types of incomplete combustion and contain several carcinogenic components like benzo[a]pyrene (BaP); oxygenated hydrocarbons including aldehydes (e.g.: formaldehyde), cetones (acetone), alcohols (e.g.: methanol) and organic acids (formic acid) are all respiratory tract and mucous membrane irritants. Some VOCs, including benzene, chloroform and formaldehyde, are considered carcinogenic.

The photochemical reaction of NO_x with VOCs forms secondary pollutants collectively known as photochemical smog. This smog includes ozone (O_3) on the ground (tropospheric), various free radicals, oxygenated hydrocarbons like aldehydes, and peroxyacetyl nitrates (PAN). All can be respiratory irritants, and some are mutagenic (PAN) or carcinogenic (formaldehyde). Smog is a concern because of the health problems it causes and because it is an urban atmospheric pollutant that is on the rise in Canada.

CH_4 is one of the principal greenhouse effect gases. Although generally released in far smaller quantities than CO_2, its warming effect is 25 to 30 times greater and so its overall effect on global warming is not negligible. In Canada, oil and gas exploitation is the second most important source of methane emissions, after the biogas from sanitary landfill sites and dumps.

Plant construction and operation of the plant could cause noise disburbances for animals or humans in the vicinity. Noise is generally defined as any acoustic energy likely to alter physical or psychological well-being. The standard measure is the mean value of equivalent noise level (L_{eq}) per time unit (24 hours, for example). It is measured using the decibel scale, a logarithmic scale, meaning that noise doubles in intensity with each increase of 3 decibels.

The World Health Organization (WHO) proposes an indoor residential limit of less than 45 dB(A) during the day and 35 dB(A) at night. Its outdoor daytime limit is 50 dB(A) L_{eq} and 45 dB(A) L_{eq} at night. Over 55 dB(A), the nuisance level in a residential neighbourhood is considered serious. In industrial zones or work environments, a level of 75 dB(A) L_{eq} (8 hours) is considered acceptable. These standards are currently under review. The main problems of noise are loss of sleep, communication problems, effects on the performance and behaviour of students and a feeling of decreased quality of life. Chronic exposure can cause increased blood pressure.

Construction would inevitably result in a loss of land fauna habitats (mammals and birds) and aquatic habitats (water fowl, fish, invertebrates) over an area of at least 64 hectares (surface cleared for installation) as well as potential soil and water pollution through accidental hydrocarbon spillages.

Construction near the marine shore would impact on this ecosystem, causing pollution and increased turbidity through runoff and the destruction of benthic habitats essential to animals living on the ocean floor. Plant operation could impact negatively on the marine ecosystem, since 300,000 litres of seawater per minute would be used to cool the refrigeration gases. Water returning to the ocean would be 0.5°C higher in temperature. This increase would not be likely to disturb large marine animals or fish, but could affect benthic fauna and flora.

The surface required for the plant and its perimeter would necessitate the destruction of plant and animal habitats used as food resources by the native population. Accidental spillage of petroleum products during construction or of various chemical products during operation could contaminate land and water resources in a larger area if restraining basins and protective dikes around reservoirs and channels are not able to retain the liquids.

Impacts linked to the construction and operation of a deep-water transshipment port

The construction of a deepwater port would increase water turbidityin the port, and ship movements would increase turbidity within an area of a few hundred metres from the dock. Turbidity and the displacement of the seabed by the turbulence of ship propellers would impact on the benthic fauna, in some cases seriously. Sediments in the water would also create various problems for fish by burying habitats and interfering with respiration and reproduction. These effects would be negligible among marine mammals, which have a broader habitat base and can avoid affected regions. The spillage of LNG or tanker fuel could have major impacts, depending on the extent of the spill. Bird life is generally the most severely affected, as has been proven by numerous oil spills since the 1960s.

Human health is not directly threatened by the construction and presence of a deepwater port. However, there is always the risk of LNG leaks and explosions. Port zone workers would be at the greatest risk of potential injuries and fatalities A Quebec study on the transshipment of propane gas estimated that the annual risk of accident associated with faulty ship-loading systems operation would be about 10^{-4} with a mortality rate of about 10^{-2}/year. Human health would be indirectly affected if occasional spills of petroleum products contaminated the sea water through a bioaccumulation of certain substances in the last links of the food chain - in this case, carnivorous fish and marine mammals that may be part of the human diet.

Sector: Energy Activity: Natural Gas Transportation and Liquefaction

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- rupture in pipeline, conduits or reservoirs	- destruction of land, aquatic and marine habitats	-primarily site and perimeter, may also be regional	- regular inspection, emergency measures planning - confinement	- appropriate CSA standards like Z184 and Z276-M1994
	- explosion				
	- fire				
Gaseous or air emissions	- CO_2	- greenhouse effect	- global	-containment of CO_2 extracted from natural gas	- none
	- CH_4	- greenhouse effect	- global	- prevention of leaks	- none
	- No_x	- toxicity, formation of smog and ozone on ground	- local and regional	- antipollution systems	- 200 µg/m^3 (24h) for NO_2
	-VOC	- toxicity, formation of smog and ozone on ground	- local and regional	- containment or ↑ combustion performances	- none
Liquid emissions or discharge into water	- suspended solids	- unhealthiness, disturbance of aquatic life	- downstream waterways or marine perimeter	-preventive measures, but hard to monitor	- for pollutants overall: Fisheries Act (Canada); Cdn Environmental Assessment Act; applicable provin-cial laws (B.C. Environmental Assessment Act)
	- hydrocarbons	- unhealthiness, toxicity for aquatic life	-downstream waterways or marine perimeter	- confinement, but hard to monitor	
	- diversion or drainage of waterways and wetlands	- destruction of wildlife habitats	- waterways or wetlands, site and perimeter	- mitigation measures	
Solid emissions or discharge into soil	- destruction of forest and land habitats	- loss of wildlife habitats, wildlife disturbance	- site and perimeter	- reduction of destroyed surfaces, appropriate mitigation measures	- Migratory Birds Act (Canada); Cdn Environmental Assessment Act; B.C. Env. Assessment Act.
	- hydrocarbon spillage	- appearance, toxicity for animals	- site and perimeter	- prevention and confinement	
Nuisances	-noise and dust	- wildlife disturbance, unsanitary	- site and perimeter	- noise mitigation measures and dust control	- L_{eq} 45 dBA(night) and 55 dBA (day) (WHO standards); Canadian Environmental Assessment Act; B.C. Env. Assessment Act
Indirect impacts or other exposures	- social conflict	- economic	- local and regional communities	- financial compensation, communication	- Indian Act, treaty concluded with Amerindians
	- loss of ancestral and archaeological sites	- heritage and cultural value	- local and regional Aboriginal communities	- communication, artifact displacement, project modification	-Heritage Conservation Act (B.C.)

	- modification in traditional Aboriginal diet	- N.A.	- local and regional Aboriginal communities	- mitigation measures, communication, project modification	-???

STRESSOR/ EXPOSURE	Effect on Health	Population at Risk	Probability of Occurrence	Environment/ Biological Indicator (Monitoring)	Information/ References
Technological disaster	- respiratory irritations, burns, trauma, death	- primarily workers, also population inhabiting the perimeter	- very rare, about 10^{-7} to 10^{-2} deaths per year	- accident, morbidity and mortality reports - explosimeter	
	- unknown	- global	- frequent	- measure in ambient air, average annual temperature	
	- asphyxia, unknown for climatic change	- workers (asphyxia) and global (climatic change)	- rare and frequent	- measure in ambient air, explosimeter, average annual temperature	
Gaseous or air emissions	- irritation of respiratory tracts, smog provoking inflammation	- urban zone residents	- occasional during very hot periods	- measure in ambient air	
	- irritation of respiratory tracts, smog provoking inflammation	- urban zone residents	- occasional during very hot periods	- measure in ambient air	
	- N.A.	- N.A.	- N.A.	- N.A.	
	- toxicity, potentially carcinogenic if presence of PAH	- consumers of drinking water	- rare or unknown	- measure of concentration in water	
Liquid emissions or discharge into water	- N.A.	- N.A.	- N.A.	- N.A.	
	- N.A.	- N.A.	- N.A.	-N.A.	
	- toxic, potentially carcinogenic effects	- workers handling soil	- rare or unknown	- measure of concentration in soil	
Solid emissions or discharge into soil	- quality of life, sleep disturbance, stress, aggressiveness, hypertension	- workers and peripheral residents	- rare to frequent	- measure of external and internal ambient noise, complaints, medical follow-up	
	- individual and group stress	- neighbours and communities	- occasional	- property assessment follow-up, perception studies	
Nuisances	- quality of life, stress	- local and regional communities	- occasional and frequent	- complaints, community perception	
Indirect impacts or other exposures	- lifestyle changes, health problems like cardiovascular disease	- local and regional communities	- occasional and frequent	- community perception, long-term medical follow-up, epidemiological studies	

References

PAC-RIM LNG Inc (1995) Project Approval Certificate Application PAC-RIM LNG Inc. PAC-RIM LNG Inc, Calgary, 192 p. + appendices.

BAPE (1991) Proket Soligaz: approvisionnement et entreposage souterrain de liquides de gaz naturel à Varennes. Rapport d'enquête et d'audience publique, Bureau d'audiences publiques sur l'environnement, Gouvernement du Québec, 101p.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Transportation and communication

Road-building projects

Quebec's road network extends over some 62,000 kilometres. Although network expansion has slowed markedly since the middle 1980s, there are still some major highway construction projects. The government also carries out regular heavy work throughout the network, bypassing cities and towns, straightening curves, leveling hills, widening bridges, etc. Justification for this work is generally that of ensuring smooth traffic flow and greater safety; this is the reason for building new city or town bypasses and altering the lie of regional roads.

There are two types of impacts related to road construction: temporary impacts associated with the construction phase and permanent impacts due to the road's existence.

Temporary impacts associated with road construction or redevelopment

One of the most obvious impacts resulting from road system development is heavy truck and equipment traffic. The problems arise from the rate of truck traffic, their speed, the noise created and the dust raised by the pounding action of the heavy machinery. Because the work schedule on the construction site is an important factor, work is usually restricted to between 7:00 a.m. and 6:00 or 7:00 p.m.

It should be remembered that the World Health Organization suggests a maximum noise level of 45 dB(A) at night in a bedroom and a maximum of 55 dB(A) outside during the day. Occasionally, the outside noise level may be exceeded when heavy trucks pass by or when certain equipment is being used (mechanical digger, grader, etc.).

Dust is actually formed by particles suspended in the surrounding air. Work such as road building, that requires the use of mechanical processes, normally produces large particles which are less of a concern with respect to contributing to health effects, than small particles which penetrate more easily into the lungs. Studies have linked particulate matter in the air to a variety of adverse health effects ranging from transient mild respiratory symptoms to aggravation of cardiorespiratory conditions and even premature death. While generation of dust from road construction will generally result in temporary exposures for nearby residents, subsequent road traffic can generate long-standing exposures to particulate matter in relation to both road dust and vehicle emissions. Road crews are likely to experience continued exposures as they move from one site to another.

It must also be stressed that the construction phase may create safety problems for the crew, the residents and the drivers who must pass through the construction site. Explicit signage is a fundamental preventive measure for avoiding accidents. The hazards of dynamiting must also be mentioned.

Psycho-social impacts

Road construction or upgrading may lead to certain psycho-social problems, most notably expropriation, destructuring of the agricultural setting and urban spread.

Expropriation often means the relocation or even demolition of one's principal residence. When it is unnecessary to move the house, proximity to the road may lead to fears for safety in addition to noise and dust problems. The existence of a right-of-way at the home's "front door", as well as loss of landscaping, inevitably causes a depreciation in the value of the home even if the municipal assessment remains essentially unaltered. The repercussions expected in these cases are stress, a reduced quality of life and, possibly, financial loss when the property is sold.

Agricultural disorganization occurs when land is abandoned because it has become inaccessible or difficult to cultivate, due to the addition of numerous urban infrastructures. Crisscrossing the territory with expressways divides up agricultural land, restricting accessibility or reducing its quality. It also leads to latent speculation which prevents agricultural activity from starting again. Farmers, whose land is truncated or disorganized to a point that affects the quality of what remains, are likely to experience stress from these events.

Urban spread is another consequence of building roads or highways that make rural land accessible. As part of the urban spread, suburbs appear, creating a growing need for services and increased health costs, while also draining the city core. This in turn generally results in increased crime and poverty and the appearance of a relatively unhealthy environment, which is detrimental to the overall quality of life.

Noise

As seen in various road-building sites, construction or upgrading can be the source of significant noise disturbances. For example, during the upgrading of Montreal's Metropolitan expressway in the summer of 1990, the resulting noise level varied between 65 and 80 dBA within a 30 metre radius of the work, encompassing the closest homes located only about 10 metres away. This qualifies as a highly disturbing noise level that causes stress reactions, the inability to concentrate and even bad moods. Some of the work such as hydro demolition and sandblasting resulted in noise levels between 80 and 95 dbA over a 30 metre radius. Over a period of several hours, such levels are unacceptable.

Another major source of sound disturbance on the road system is traffic. Noise is usually produced by the mechanical friction between moving parts, air moving around a vehicle and friction between the tires and the road. In the last case, a vehicle doubling its speed increases sound by 9 to 13 dbA while water on the road causes a 10 dBA increase. Urban expressways are a source of significant sound disturbance. In Quebec, the average sound volume recorded within a radius equal to the distance of the first row of houses alongside urban and suburban expressways is 70 to 75 dbA, a level that is clearly stressful.

There are various ways to reduce traffic noise. Limiting speeds is one way, but speed limits are rarely respected. Another fairly effective, as well as aesthetic, means of reducing noise, is planting an absorbent vegetation zone such as trees or bushes. However, in urban and surrounding areas where available space is limited, this is impossible. For these applications, noise-reduction screens made of various materials including concrete, steel, plastic and soil embankments were selected. It is necessary to point out, however, that the resulting noise reduction of 10 to 15 dBA still leaves a moderately disturbing residual noise level of 60 to 65 dBA.

Air pollution

The primary organic pollutants generated by combustion motors are nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2) and volatile organic compounds (VOCs). In countries that prohibit leaded gas, manganese (Mn) has now also become an important inorganic pollutant. The presence of particles in the air carried from elsewhere by vehicles or sent into the air by high speed travel must also be emphasized.

That motor vehicles cause air pollution requires no further proof. According to a Quebec government report describing the evolution of air pollution from 1975 to 1994, the main source of atmospheric contaminants is transportation. This category alone represents 52% of all pollutant emissions, or just over 1.65 million tonnes in Quebec in 1994. CO, NO_x and VOCs are the pollutants generated in the highest amounts by vehicles.

Nitrogen oxides (NO_x) are composed of several molecules and include the nitric oxide (NO) and nitrogen dioxide (NO_2) emitted when fossil fuels are burned at high temperatures. NO_2

is a brownish, irritating, acrid gas whose toxicity is due to its ability to oxidize cellular membrane components. Mild to severe exposure to the gas causes a loss in odour perception, breakdowns in pulmonary function and eventually pulmonary oedema. One of the major effects of chronic exposure to NO_x is emphysema and reduced forced expiratory volume. It is also important to note the characteristic ability of NO_2 to react with VOCs to form the secondary pollutant, photochemical smog.

Volatile organic compounds (VOCs) are basically hydrocarbons that can vaporize at room temperature. Several of the thousands of VOCs are fairly toxic. A high concentration of benzene, a carcinogen for humans, is one of the VOCs found in gasoline.

An oxidation reaction between NO_x and VOCs causes the formation of secondary pollutants collectively known as photochemical smog. At ground level (the troposphere), this smog contains ozone (O_3), different free radicals, aldehydes, formaldehyde and a group of substances called peroxyacetylnitrates (PAN). All these substances are highly irritating to the respiratory system and some are even mutagens (PAN) or carcinogens (formaldehyde).

Water pollution

Vehicular traffic causes a variety of substances to be deposited on the road surface: oils, grease, hydrocarbons and different body metals. Tire wear releases approximately 50 milligrams of hydrocarbons per kilometer. Deposits of these pollutants on the roadway or the shoulder are later washed away by rain or snow-melt runoff into nearby watercourses. Several heavy metals, most notably cadmium, copper, lead, iron and zinc, can be identified in the runoff. Iron and zinc are found in the highest concentrations. Public health problems arise when potable water wells are contaminated by any of these pollutants.

Snow and ice removal products

Each time there is snow or ice on roadways, a variety of ice melters and abrasives are spread on them. The most common ice melter is sodium chloride (NaCl). However, below -15°C, calcium chloride ($CaCl_2$) must be used as it provides more effective melting at very low temperatures. The abrasives used to prevent slipping and sliding on icy sidewalks or roads contain sand, gravel or crushed rock.

Water produced by road ice melting is usually characterized by an alkaline pH (pH of 8.5), high conductivity and turbidity, and the presence of chlorides, and sodium and calcium ions. The concentration of chlorides in the runoff water can range from 3,500 to 10,000 mg/L. This is a very high content considering that, for sensory purposes, the acceptable limit in raw feed water should not exceed 250 mg/L. Chlorides in the runoff do not usually present a direct health risk for humans unless free ground water contaminates wells supplying drinking water.

Impacts of road network upgrading

The impacts of building or redeveloping roads are not solely negative. Straightened curves, leveled and re-paved road surfaces, better intersection layout, improved signage and lighting, the presence of guardrails and crash barriers all help reduce the number of traffic accidents and consequently, mortality and morbidity.

Sector: Transportation and Communication
Activity: Roads and Highways

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster					
Gaseous or atmospheric emissions	- suspended particles	- pollution	- local and regional	-	- 150 $\mu g/m^3$ (24 h); Q-2 atm. qual. reg.
	- nitrogen dioxide (NO_2)	- pollution	- local and	- catalytic reduction	- 0.2 ppm (1 h) and 0.1 ppm (24 h); Q-2 atm. qual. reg
	- volatile organic compounds (VOC)	- pollution	regional	- catalytic reduction	- none
	- photochemical smog	- pollution	- local and regional	- reduce No_x and VOC	- 0.08 ppm (1 hr); Q-2 atm. qual. reg
	- carbon dioxide (CO_2)	- climate warming	- local, regional and continental - global	- reduce combustion	- none
Liquid or waterborne emissions	- heavy metals:	- toxicity to aquatic organisms	- captor watercourses	- none	- 0.05 mg/L for Pb (Q-2 drinking water qual. reg.)
	primarily Cu, Fe,	- toxicity tp aquatic organisms	- captor watercourses	- none	- 250 mg/L, Env. Can. guideline for raw water supply
	Pb and Zn - oil and grease - chlorides	- toxicity to aquatic organisms	- captor watercourses	- reduce use of de-icing salts	- none
Solid or soil-borne emissions					
Disamenities	- noise	- salubrity	- along the roadside - construction site	- speed limits; sound-absorbing screen	- L_{eq} 45 dBA 8h nighttime and 55 dBA daytime
Indirect impacts or other exposure	- risk of vehicles striking animals	- death of animals struck	- on the roadways	- restrict animal crossings (fencing) and post crossing signs	- road safety
	-accidents during construction	- N.A.	- construction site and perimeter	- impose speed limits, preventive measures	- guidelines for construction contractors
	- subdivision of agricultural lands	- disorganization, downgrading of agricultural lands	- agriculture in suburban settings	- protect agricultural lands	- Agricultural Lands Protection Act

STRESSOR/ EXPOSURE	**Effects on Health**	**Population at Risk**	**Probability of Occurrence**	**Biol./Environmental Monitoring Indicators**	**Information/ References**
Technological disaster					
Gaseous or atmospheric emissions	- irritations, respiratory problems, infections	- mostly workers	- rare to occasional	-suspended particles in ambient air	- Lajoie (1997) Hamilton and Harrison (1991) Bisson and associates (1997)
	- respiratory tract irritation, pulmonary edema	-urban zone residents	- rare or unknown	- ambient air NO_2 measurement	
	- benzene: carcinogen; toluene: fetal malformations	- urban zone residents, pump tenders (gas pumps)	- rare or unknown	- ambient air VOC measurement (notably benzene and toluene)	
	- ozone: pulmonary tissue inflammation	- urban and suburban zone residents	- rare to occasional in Canadian cities	- ground-level (tropospheric) ozone measurement	
	- climate changes	- global	- frequent	- atmospheric CO_2 measurement	
Liquid or waterborne emissions	- varied toxic effects (no carcinogenic metals in this case)	- people drinking polluted water	- unknown	- level of heavy metals in drinking water	MEF (1991) Environment Canada (1987) Goyer (1980) Hamilton and Harrison (1991) Delisle *et al* (1991)
	- if PAH present: possible carcinogenic and mutagenic effects	- people drinking polluted water	-unknown	-level of PAH in drinking water	
	- no remarkable effect	- people drinking polluted water	- N.A.	- level of chlorides in drinking water	
Solid or soil-borne emissions					
Disamenities	- sleep quality, stress - stress, hearing problems	- vicinity - workers	- frequent to very frequent - occasional to frequent	- dBA measurement at various distances from the road system	- BAPE reports ; Lévesque and Gauvin (1996)
Indirect impacts or other exposure	- injuries, death	- vehicle drivers and passengers	- occasional	- public safety, morbidity/mortality reports	
	- injuries, death	- workers, residents, drivers	- rare	- public safety, morbidity/mortality reports	

	- stress, social conflict	- farmers	- occasional to frequent	- complaints, perception studies	

References

BAPE (1992) *Prolongement de l'autoroute 55 de Saint-Célestin à l'autoroute 20.* Rapport d'enquête et de médiation, Bureau d'audiences publiques sur l'environnement, Government of Quebec, 65p.

BAPE (1993) *Autoroute 55: doublement de la chaussée entre Bromptonville et l'intersection du chemin de la Rivière.* Rapport d'enquête et de médiation, Bureau d'audiences publiques sur l'environnement, Government of Quebec, 77p.

BAPE (1993) *Liaison autoroutière Sainte-Luce—Mont-Joli.* Rapport d'enquête et de médiation, Bureau d'audiences publiques sur l'environnement, Government of Quebec, 179p.

BAPE (1995) *Projet d'amélioration de la route 132 à Pointe-au-Père.* Rapport d'enquête, Bureau d'audiences publiques sur l'environnement, Government of Quebec, 48p.

BAPE (1997) *Liaison routière Lachute-Masson, autoroute 50.* Rapport d'enquête et de médiation, Bureau d'audiences publiques sur l'environnement, Government of Quebec, 196p

Bisson and associates (1997) *Air Quality in Quebec (1975-1994).* Ministère de l'Environnement et de la Faune, Government of Quebec, 52p.

Canada (1991) The State of Canada's Environment. Environment Canada, Government of Canada, 787p.

Delisle, C.E., M.F. Lapointe, A. Leduc (1990) *L'échantillonnage des neiges usées en milieu urbain; résultats de l'hiver 1989-1990.* Sciences et techniques de l'eau, November: pp. 391-395

Environment Canada (1987) *Canadian Water Quality Guidelines.* Environment Canada, Government of Canada, 564p.

Goyer (1980) *Vue d'ensemble sur les substances toxiques: huiles et graisses.* Bureau d'étude sur les substances toxiques, ministère de l'Environnement, Government of Quebec, 74p.

Hamilton, R.S. and R.M. Harrison, editors (1991) *Highway pollution. Studies in Environmental Science #44.* Elsevier Science Publishing Company, 510p.

Lajoie, P. (1997) *Particules dans l'atmosphère: des normes plus sévères pour protéger la santé.* BISE (Bulletin d'information en santé environnementale), 8(3): 1-4.

Lajoie, P. (1997) *Pollution de l'air reliée au transport en milieu urbain: impacts sur la santé de la population.* In, Levallois, P. and P. Lajoie, *Pollution atmosphérique et champs électromagnétiques.* Presses de l'Université Laval, pp. 51-71.

Lévesque, B. and D. Gauvin (1996) *Le bruit communautaire.* BISE (Bulletin d'information en santé environnementale), 7(1):4-6.

MEF (1991) *Guide pour l'aménagement des lieux d'élimination des neiges usées*. Ministère de l'Environnement et de la Faune, Government of Quebec, 95p.

MEF (1992) *État de l'environnement au Québec, 1992*. Ministère de l'Environnement et de la Faune, Government of Quebec, Les éditions Guérin, 560p.

MTQ (1995) *Politique de sécurité dans les transports, volet routier; une vision sécuritaire sur des kilomètres*. Ministère des Transports, Government of Quebec, 103p.

Hydro lines

As mentioned in the section dealing with the impacts of hydroelectric dams, Quebec is the world's third-ranking producer of electricity, with a power base of 40,000 megawatts (MW), 75% of which is produced by the provincially owned corporation, Hydro-Québec. Electricity is sent to users first over the transmission network and then over the distribution network. The first carries the electricity over great distances using high voltage lines of 44 to 735 kilovolts (kV). For simplicity's sake, we can say that the transmission cables are normally strung from metal towers. The subject of this section is Hydro-Québec's transmission network, which extends over some 37,000 kilometres. The distribution network used to carry electricity to each point of use is more than 96,000 kilometres long. At less than 34.5 kV, the distribution network's electric transmission cables are lower voltage and are normally strung from wooden poles.

Characteristics of the transmission network

The type of electric transmission network was greatly influenced by how Quebec produces electricity: that is, in megaplants that are frequently far removed from consumer areas. Hence, electric transmission from the La Grande complex, from Churchill Falls (Labrador) and the Manicouagan-Outardes-Bersimis complex required stringing 735,000 volt (735 kV) transmission lines over thousands of kilometres. The cables are strung from braced lattice-type towers that can reach a height of 60 metres. Closer to major urban centres, transformer stations reduce the tension to 315 kV, and the 315 kV lines carry the current to other stations for further reduction to the distribution network.

The transmission network is therefore primarily composed of lines carrying 120, 230, 315 and 735 kV, all of which are alternating current. The cables for these lines are carried on lattice-type towers whose height varies according to the tension. For several years now, more aesthetically pleasing tubular towers have been used in urban areas. There is one exception here: the Radisson-Nicolet-Des Cantons line (near Sherbrooke) is a 1,120 kilometres long

450 kV direct current line that crosses the river at Grondines (Portneuf region) and was designed primarily to export electricity to the United States.

Tower height and width are determined by standards that set the horizontal clearance (distance between the cables), vertical clearance (the minimum distance between the ground and a cable at its lowest point between two towers) and phase clearance (distance between cables located on both sides of the tower). Since these distances increase as tension increases, vertical clearance ranges from 13 to 18.6 metres for a 735 kV line (depending on the obstacle in question, road, railway track, private road, etc.) and from 6 to 9.4 m for a 315 kV line.

Impacts related to building a high-tension line

Impacts solely related to the construction phase, which disappear once a line is in service, usually result from the presence of various machinery and traffic. Main disturbances include noise, dust, exhaust fumes, electrical appliance interference and the safety of the nearby population. They are similar to those experienced near any construction site (buildings, roads, etc.). Measures such as using dust control liquid, prohibiting machinery operation at night, etc. must be implemented to mitigate them. When the line has to span a watercourse, the presence of heavy equipment, the building of temporary dams and the disposing of plant debris in the water are likely to cause significant disturbances in the aquatic habitat. Attempts must be made to protect the habitat of migratory and sport fish. In the case of large watercourses, building temporary dams can also cause floods by backing up ice during the spring thaw.

Permanent impacts due to the presence of high-tension lines

The following is a summary of the many permanent repercussions. Note that the issue of electromagnetic fields is described in the next sub-section.

Incorporating the power line into the natural and traditional landscape

Populations living in the vicinity of high-tension lines are increasingly concerned by the visual impact. It is considered inappropriate to have electric cables appearing in unique landscapes or near historical buildings. Spans over watercourses are also a major source of aesthetic concerns. In this type of situation, public pressure forced a 450 kV line to be run underwater across the St. Lawrence River in Portneuf county. In 1996, the BAPE also recommended that the 315 kV Duvernay-Anjou line be run under the rivière des Prairies.

Static noise generated by power lines

High-tension cables give rise to discharges producing a phenomenon called a "corona effect" and "crackling" that may even be heard in dry weather. Hydro-Québec estimates the maximum noise level at the edge of the right-of-way during a light rain to be 42 decibels (dBA) and no higher than 36 dBA at the closest homes. In dry weather, the intensity of this same noise would not exceed 15 to 25 dBA, making it almost inaudible. Given that existing standards or regulations for residential areas define the limits as 40 to 50 dBA at night and 45 to 55 dBA during the day, static noise is not deemed to be a real nuisance.

Collision hazards for moving objects

Some incidents have demonstrated the risk of small airplanes colliding with high-tension lines. From 1975 to 1995, Canada recorded approximately 400 airplane collisions with cables. These accidents took the lives of more than 100 people. At the rate of 20 accidents per year, this concern cannot be ignored and it should be addressed each time high-tension lines are in the vicinity of smaller airports.

When towers have to be raised in navigable watercourses, the potential for boat collisions must be addressed. This issue applies primarily to the passage of large ships, which may require several hundred metres to come to a full stop. The problem was raised at BAPE hearings studying the 450 kV line crossing the river at Grondines.

Economic depreciation

As the study on the Duvernay-Anjou line between Laval and Montreal showed, putting a new high-tension line into service in a highly urban setting is likely to hinder residential development. Condominium and old-age home developers, as well as single family home owners expressed concern about this.

Recreation and tourism potential can also be affected. Electric towers and cables are not compatible with some existing infrastructures such as natural parks, campgrounds or even natural panoramic observation points.

Electromagnetic fields (EMF)

Perhaps the greatest fear expressed by people living in very close proximity to high-tension lines is exposure to electromagnetic fields. Much scientific literature has been published on this subject, making it relatively well documented. But, understanding the effects of electromagnetic fields first requires knowing what they are and how they act on living organisms.

The nature of electromagnetic fields

Two types of fields form an EMF: the electric field and the magnetic field. An electric field (EF) is generated the moment there is a tension variation in the line. One must realize that an EF exists the moment there is current in the cable even if no electric device is turned on (for instance, a lamp that is plugged in but turned off). The electric field is measured in volts per metre (V/m) or kilovolts per metre (kV/m). In a home, the average EF is 12 V/m, while the EF generated by a 735 kV power line can reach 10,000 V/m directly underneath the line. The magnetic field (MF) is generated by the passage of the electric current and its intensity is expressed in micro-Tesla units (μT). Contrary to the electric field, the MF is only generated when current is used (i.e., when the lamp is turned on). The ambient domestic magnetic field usually varies between 0.1 and 0.2μT while the maximum MF produced by a high-tension line ranges from 10 to 30 μT. Unlike the EF, the MF passes through most structures, such as buildings and the human body, without changing.

These two fields (electric and magnetic) exist together in the environment, hence the term electromagnetic field (EMF). One of the characteristics used to describe an EMF is its frequency expressed in Hertz (Hz). Electromagnetic fields emitted by transmission networks have a very low frequency of 1 to 300 Hz. Domestic electrical wiring in Quebec generates an EMF frequency of 60 Hz.

EMF sources and exposure levels

The levels of exposure to a natural electric field and magnetic field are very low, at about 0.001 V/m for the EF and 10^{-12} μT for the MF. Average domestic exposure to an EF of 12 V/m and a MF of 0.1 to 1 μT is caused by the presence of our industrial society's electrical lines and apparatus. The daily use of various appliances generates a significant amount of EMF. Appliances such as toasters, irons, refrigerators and colour televisions generate an EF of 30 to 60 V/m and a MF ranging from 0.3 to 4 μT. It is noteworthy that a hair dryer produces an EF of 60 V/m and a MF ranging from 7 to 70 μT over a usage distance between 30 cm and 15 cm. An electric blanket generates a MF of 10 μT at a distance of 1 cm, but an EF of about 10 kV/m.

The EF generated by various household appliances and the average domestic EF are much lower than that generated by a high-tension power line. At ground level under the lines, the maximum EF of the line is 10kV/m while at the edge of the right-of-way it is 2 kV. And the maximum 30 μT MF under the cables of a 735 kV line decreases to 14 μT at the far edge of the right-of-way. At a horizontal distance of 100 metres from the cable, the MF would only be 0.1 μT, or similar to the average domestic MF exposure.

The concept of fields and induced currents

Since they are good conductors, living organisms capture what are called induced currents emitted by the EMF. These are measured in milliamperes (mA). Because the currents induced by the EF and the MF are normally perpendicular, the EF induces a current that flows from head to foot in the body of a person standing under an electric line, while the MF induces a current that flows in a more circular pattern through the body's most conductive fluids, tissues and organs.

In the case of a 10 kV/m EF, which corresponds to the maximum intensity measured at ground level beneath the cables of a 735 kV line, the maximum induced current in the organism is about 0.16 mA. This is well below the 0.66 to 1.0 mA sensory threshold. For reference, the sensory threshold is 0.5 to 1.0 mA. Respiratory arrest can occur from muscle tetany at between 18 and 30 mA, and cardiac arrest from ventricular fibrillation can be caused by a current ranging from 30 to 120 mA.

Biological effects of EMF under experimental conditions

Numerous studies conducted between 1975 and 1995 have shown a whole series of biological effects on a variety of animals. In terms of the neuroendocrinological system, disturbances of the diurnal rhythm and a marked decrease in melatonin secretion in the rat and mouse were observed at an EF ranging from 2 to 130 kV/m. An EF between 3 and 30 kV/m upsets the nervous system primarily by affecting dopamine and serotonin. In the human, a slight decrease in cardiac rhythm was observed at an EF of 9 kV/m and a MF of 20 μT. Chicken and bird embryos showed significantly more deformities in the presence of a MF ranging between 100 and 1,200 μT.

Possible carcinogenic effects of EMF on humans

Due to the existence of many contradictory studies, or studies which present more or less significant results, the carcinogenic effect of EMF is a highly controversial subject. What can be said is that there is no direct proof that an EMF stimulates cancer in adult humans. Even the most recent, strictly controlled studies provide inconsistent results. They neither prove nor disprove the hypothesis of a link between EMF and cancer. Although there is no clear trend, several results indicate relatively positive risks (>1) that are still insignificant (less than 2). On the other hand, epidemiological studies of children support some type of relationship between cancers and the levels of the magnetic fields generated by power lines. The results of various studies show that, generally speaking, children with leukemia lived close to electric infrastructures more frequently than children in good health. Although a causal relationship cannot be proven, the possibility of such a relationship should nevertheless be considered.

EMF exposure criteria or standards

There is no specific regulation for general EMF exposure. The International Radiation Protection Association (IRPA) recommends that the general public's exposure over 24 hours be limited to 5 kV/m for EF and 100 μT for MF. For the workplace, these recommendations are 10 kV/m and 500 μT respectively. Currently, there are no recommendations or guidelines for EMF exposure in Canada. The few American states that have regulated exposure to the electric field within a high-tension line right-of-way have set the limits between 8 and 10 kV/m.

The concept of careful avoidance

It must be said that, just as scientific research on the effect of EMF on public health has not clearly indicated the existence of a significant risk, neither has it proven the complete absence of risk. In this situation, careful avoidance is recommended. This concept, developed at Carnegie Mellon University, Pittsburgh, recommends taking certain simple measures to reduce the population's exposure to EMF. Because of the precedents it embodies, the application of this concept has given rise to much debate among business, public and scientific organizations. In 1996, Hydro-Québec felt that careful avoidance represented a conceptual departure from the ethics of public health, since the carcinogenic properties of EMF had not yet been identified.

Maintaining high-tension line rights-of-way

Approximately 20,000 of Hydro-Québec's 120,000 hectares of rights-of-way require annual maintenance to remove bush and tree growth so towers and lines can be maintained. Removing this dendriform vegetation also helps limit potential damage from forest fires, of which the canopy flames burn at temperatures up to 800°C. Vegetation beneath the cables must be low and the right-of-way wide enough to prevent the forest fire's convection column from affecting the conductors.

There are two possible means of removing vegetation: mechanical clearing and clearing with phytocides (herbicides).

Mechanical Clearing

A certain number of occupational health hazards accompany the use of chain saws and strippers. For the whole of the country, workers in forestry operations have more work-related accidents than in any other trade in Canada. Between 1987 and 1989, there were 1,579 work accidents, for a total of 87,108 lost days of work, in Quebec among forest workers using chain saws. In addition, the use of vibrating tools for long periods of time leads to what is known as the "white hand" syndrome. The average prevalence of this syndrome is 30.5% among chain saw users but it increases with the number of years this work is done. After 20 years, 53% of workers are affected. The use of tobacco is an aggravating factor here. Acoustic trauma is another health hazard for workers using chain saws. At full speed, the noise level of a mechanical saw rises to between 105 to 115 dBA and after 10 years at such noise levels, 55% of workers run the risk of professional deafness.

Risk studies also focus on exposure to gaseous pollutants emitted by motorized tools. The main pollutants to which these workers are exposed include benzene, carbon monoxide, formaldehyde and polycyclic aromatic hydrocarbons (PAH).

Many of the studies conducted since the 1980s agree that exposure to benzene increases the risk of leukemia. In epidemiological investigations, exposure to high concentrations of benzene in the occupational environment has consistently been associated with increased risk of leukemia. Chain saw operators inhale air containing between 0.1 and 2.4 mg/m^3 of this gas. The United States Occupational Safety and Health Administration (OSHA) has set an exposure standard of 3 mg/m^3 in the work atmosphere while the National Institute of Occupational Safety and Health (NIOSH) recommends that the standard be reduced to 0.3 mg/m^3. In Quebec, the workplace exposure standard used by Hydro-Québec for its risk assessments is 30 mg/m^3.

On average, workers are exposed to 34 mg/m^3 of carbon monoxide (CO), a level that represents 60% of the maximum 57 mg/m^3 exposure. However, the American Conference of Governmental Industrial Hygienists (ACGIH) suggests that exposure be limited to 29 mg/m^3. The average level of carboxyhemaglobin found in chain saw operators is 5%.

The air surrounding chain saw operators also contains 0.08 mg/m^3 of formaldehyde. This is lower than the 2 to 3 mg/m^3 level which causes symptomatic irritation of the respiratory mucosa and the eyes. Formaldehyde has been classified as a potential human carcinogen.

Lastly, the average 0.02 mg/m^3 of PAH inhaled by workers is 10 times lower than the 0.2 mg/m^3 standard set by the Quebec Workplace Quality Regulation. In Sweden, however, the allowable limit is 0.04 mg/m^3. Many PAH compounds have been recognized as suspected or proven human carcinogens, particularly in the case of lung cancer.

Use of phytocides

Of the ten or more types of phytocides[9] that can be used to destroy vegetation (grass, scrub and dendriform), Hydro-Québec usually selects three: 2,4-D, picloram and dicamba. These three substances are homotypes of the auxin plant hormones, which act by disrupting plant metabolism and causing disorganized growth, malformations and death. As a group, herbicides are much less toxic to animals than insecticides.

Given its suspected, but as yet unproven, carcinogenic and teratogenic potential, 2,4-D is a controversial herbicide. Moreover, traces of dioxins (except TCDD) can sometimes be found in commercial 2,4-D preparations. The NOEL of 2,4-D ranges from 1 to 15 mg/kg/d for a variety of animals species. Exposure scenarios developed by Hydro-Québec claim the total exposure dose is about 0.03 mg/kg/d. It must be added that the human ADI is estimated to be 0.003 mg/kg/d. Since 2,4-D is adsorbed by the organic material in the soil, leaching into the aquatic environment will be greater from soil poor in organic material. The half-life of 2,4-D in water varies between 7 and 14 days.

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[9] Phytocide is the agreed term in forestry and herbicide is the term used in agriculture and landscaping. The same basic product can be used in both instances.

Even though picloram is a very powerful herbicide whose use is now restricted to forest applications such as clearing hydroelectric rights-of-way, no carcinogenic, teratogenic or mutagenic properties have been detected in it. This herbicide is rapidly absorbed in the gastrointestinal tract and has a half-life of 20 minutes. Nearly 90% of it is absorbed and excreted by the urinary system within 48 hours. Picloram's NOEL was set at 7 mg/kg/d and Hydro-Québec estimates the daily exposure dose to be 0.008 mg/kg/d. The ADI was set at 0.07 mg/kg/d. In 1997, based on a two-year rat study, the United States Environmental Protection Agency set a NOEL of 20 mg/kg/d and an ADI of 0.2 mg/kg/d for picloram. It must be stressed that commercial picloram preparations can be contaminated by hexachlorobenzene, a compound in the category of probable carcinogens. Like 2,4-D, picloram is retained by soil containing organic matter. Its half-life in water is about 10 days.

It is believed that dicamba, a herbicide in the benzoic acid group, may possibly be teratogenic. More than 95% of the dicamba absorbed by an animal is excreted within 48 hours. In view of the possible reproductive effects, the NOEL was set at 3 mg/kg/d while forestry workers' total exposure is estimated at 0.019 mg/kg/d. The ADI has been set at 0.030 mg/kg/d. The US EPA set the ADI for dicamba at 0.45 mg/kg/d, based on a NOEL of 45 mg/kg/d, after finding no evidence of teratogencitiy in rats or rabbits. Since dicamba is relatively mobile in soil, it leaches more readily into the aquatic environment, where its half-life is approximately seven days.

Sector: Transportation and Communication **Activity: Electric Power Lines**

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster					
Gaseous or atmospheric emissions	- combustion gases (mechanical cutting of vegetation)	- air pollution - air pollution, vegetation destruction	- site and perimeter - site and perimeter	- use fuels containing less Hx and limit exposure time - limit wind drift during spraying	- 30 mg/m^3 (QC work standards)[10] - 57 mg/m^3 (QC work standards) - 3 mg/m^3 (QC work standards) - 0.2 mg/m^3 (QC work standards) - none
	-benzene				
	- carbon monoxide (CO)				
	- formaldehyde				
	- PAH				
	- herbicides (2,4-D, picloram, dicamba)				
Liquid or waterborne emissions	- 2,4-D	All herbicides: water pollution and possible destruction of aquatic vegetation	All herbicides: site and perimeter	All herbicides: use the smallest possible effective quantities	- 0.1 mg/L (MEF drinking water reg.); 3 µg/kg/d (ADI)
	- picloram				- 1 µg/L (MEF drinking water reg.); 70 µg/kg/d (ADI)
	- dicamba				- 30 µg/kg/d (ADI)
Solid or soil-borne emissions	- herbicides (see above)	- same as above	- same as above	same as above	same as above
Disamenities	- presence of aerial cables	- depreciation of environment's visual and economic value	- vicinity and community	- burying cables when practical	- none
	- presence of towers	- agricultural activity disruption	- spanned agricultural land	- restrict passage through agricultural zone	- Agricultural Lands Protection Act
Indirect impacts or other exposure	- electric rights-of-way and access roads	- disturbance of animal and plant life	- site and perimeter	- none	- none
	- presence of aerial cables	- risk of aircraft collision	- site and perimeter	-buffer zone	- none
	- electromagnetic fields (EMF)	- radio communication disruption	- site and perimeter	- buffer zone	- apply prudent avoidance by limiting exposure

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[10] Inhalation carcinogenic risk estimate: 1/30µg.kg^{-1}.d^{-1} (EPA)

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biol./Environmental Monitoring Indicators	Information/ References
Technological disaster					
Gaseous or atmospheric emissions	- proven carcinogenic potential -carboxyhemoglobin levels - possible carcinogen - some are carcinogenic - see below	Workers form the population at risk for all gaseous pollutants - see below	- frequent: signs of eye, nose and throat irritations and cephalates - low or unknown for cancer development - see below	- workplace ambient air concentration - carboxyhemoglobinemia - workplace ambient air concentration - workplace ambient air concentration - see below	BAPE (1994) Hydro-Québec (1992)
Liquid or waterborne emissions	- possibly carcinogenic and teratogenic	All pesticides: persons visiting treated rights-of-way or living in proximity	All pesticides: rare or unknown	All pesticides: residual concentration in the immediate surroundings of the rights-of-way	BAPE (1994) Hydro-Québec (1992) Keifer (1997) EXTOXNET
	- toxic at high doses				
	- possible teratogenic				
Solid or soil-borne emissions	see above	see above	see above	see above	see above
Disamenities	- quality of life	- vicinity and community	- frequent	- complaints, perception studies	BAPE (1987, 1993, 1996)
	- quality of life	- agricultural land owners	- frequent	- complaints, perception studies	
Indirect impacts or other exposure	- N.A.	- local and Aboriginal communities	- unknown	- complaints, field studies of animal and plant life	BAPE (1987, 1993, 1996)
	- injuries, trauma, death	- aircraft passengers	- rare	- accident reports	Levallois and Gauvin (1994)
	- worry, stress	- vicinity and community	- occasional to frequent	- complaints, perception studies	Levallois *et al* (1991)
	- suspected carcinogenic property	- vicinity, primarily children	- unknown	- epidemiological studies of neighbouring populations	Levallois and Lajoie (1997)

References

BAPE (1987) *Projet de ligne à courant continu à 450 kV, Radisson-Nicolet-Des Cantons*. Rapport d'enquête et d'audience publique #22, Bureau d'audiences publiques sur l'environnement, various pagings.

BAPE (1993) *Ligne à 735 kV Des Cantons-Lévis et poste Appalaches*. Rapport d'enquête et d'audience publique #68, Bureau d'audiences publiques sur l'environnement, 401p.

BAPE (1994) *L'entretien des emprises d'Hydro-Québec sur la Côte-Nord*. Rapport d'enquête et d'audience #74, Bureau d'audiences publiques sur l'environnement, 107p.

BAPE (1996) *Projet de ligne Duvernay-Anjou à 315 kV*. Rapport d'enquête et d'audience publique #107, Bureau d'audiences publiques sur l'environnement, 192p.

El-Amrani, M., F. Gauthier and J. Turbide (1992) *Évaluation socio-économique de différents modes de maîtrise de la végétation de certaines emprises de la région manicouagan*. Société d'État Hydro-Québec (Montreal), 49p + appendices.

EXTOXNET: http://ace.ace.orst.edu/info/extoxnet/pips/ghindex.html

Hydro-Québec (1992) *Pulvérisation aérienne de phytocides; programme d'entretien des emprises 1993-1997*. Société d'État Hydro-Québec (Montreal), 466p.

Keifer, M. C, editor (1997) *Human health effects of pesticides*. Occupational Medicine: state of the art reviews, 12(2) pp. 203-411.

Levallois, P. and D. Gauvin (1994) *Les champs électromagnétiques et la santé*. Great Whale Environmental Assessment, Background Paper No. 9, Great Whale Public Review Support Office, (Montreal) 157p.

Levallois, P., D. Gauvin, P. Lajoie and J. Saint-Laurent (1996) *Bilan des normes et recommandatiions d'exposition aux champs électromagnétiques (0 à 300 GHz) et au rayonnement ultraviolet*. Institut de recherche en santé et en sécurité du travail du Québec, various numbers of pages.

Levallois, P., P. Lajoie and D. Gauvin (1991) *Les effets des champs électromagnétiques de 50/60 Hz sur la santé; bilan et perspectives de santé publique pour le Québec*. Département de santé communautaire, Centre Hospitalier de l'Université Laval, Québec, 231p.

Levallois, P. and P. Lajoie (1997) *Pollution atmosphérique et champs électromagnétiques*. Les Presses de l'Université Laval, 266p.

US Federal Register, Vol. 62, No. 92 (1997) *Notice of filing pesticide petition [picloram]*. Page 26305-26313.

US Federal Register, Vol. 62, No. 228 (1997) *Notice of filing pesticide petition [dicamba]*. Page 63164-63168.

US Federal Register, 58(225) (1993) *Pesticide tolerance for dicamba*. Page 62039-62041.

Airport construction, expansion and operation

Nature of project

The information for this analysis was drawn primarily from the 1991 impact study for the expansion of Toronto - Lester B. Pearson International Airport. The project involved the construction of three new runways to accommodate high traffic volumes. For application to similar situations in Canada, information specific to Pearson Airport will not be presented in this grid.

The construction, expansion or operation of an airport impacts on all environmental components and can have consequences for health and the human environment. Impacts from noise and the risk of plane crashes, especially in urban zones, must also be considered.

Legislation

All airport projects under federal jurisdiction are subject to a number of Canadian laws, including the *Canadian Environmental Protection Act*, which makes provisions for air, water and land protection. The Act provides for the enforcement (through regulation) of air quality objectives applying to several toxic substances in Part II, while Part IV applies specifically to federal agencies and Crown Corporations. The *Fisheries Act* protects fish and their habitats from physical destruction or toxic substances. The *Dangerous Goods Transportation Act* applies to air transport of dangerous goods in accordance with an international agreement supervised by the International Civil Aviation Organization (ICAO). Federal airport projects are also subject to environmental studies as set out in the *Canadian Environmental Assessment Act*.

Various provincial and territorial laws and municipal regulations can also frame airport construction and operation. Each province usually has a general law for environmental protection that regulates air and water quality and toxic or non-toxic solid waste production. Pesticide use, particularly on grassed sections of airports, is usually regulated by provincial law. Municipalities can regulate air quality, sewer use and domestic waste processing.

Emergencies and disasters

Along with fire or explosion, plane crashes are a particular risk for passengers, flight personnel and nearby residents. The main risks in a crash are physical destruction and fire. If a plane crashes during take-off, the disaster is more severe because fuel tanks are full. Planes also carry flammable equipment made from synthetic materials that can generate toxic gases and pollute the soil or aquatic environment.

Airports must develop disaster plans jointly with the appropriate municipal services (police, fire department, hospitals) to coordinate actions. Whether the disaster occurs inside or outside the airport zone, joint action is essential for the rapid evacuation of the injured. Cooperation between airport managers and municipal services is especially important now that government cutbacks have left several airports without independent emergency services.

Air pollution

Construction/expansion machinery and normal operations (planes, buses and vehicles circulating on the terrain) create the usual atmospheric pollutants associated with fossil-fuel engines. The principal pollutants are carbon monoxide (CO), carbon dioxide (CO_2), particulates, nitrogen oxides (NO_x) and volatile organic compounds (VOCs).

Carbon monoxide (CO) is an odourless gas that increases lethal carboxyhemoglobin. Carbon dioxide (CO_2), is one of the main greenhouse effect gases. Particulates measure 0.005 to 100 micrometres (μm) in diameter and remain airborne; only those smaller than 10 μm are absorbed into the lungs. As well as causing respiratory problems, these particulates reduce visibility and pollute the natural and human environment.

Nitrogen oxides (NO_x) include nitric oxide (NO) which transforms rapidly into nitrogen dioxide (NO_2), a brownish gas with a sharp, irritating odour that can oxidize cell membranes. This gas can decrease odour perception, alter pulmonary function and in cases of severe exposure, can lead to pulmonary edema. One of the most significant effects of chronic exposure is emphysema and a reduction in forced expiratory volume. NO_2 reacts with VOCs to form photochemical smog (see below).

Volatile organic compounds (VOCs) are hydrocarbons that evaporate at ambient temperature and exist in vapour form in the atmosphere; they number in the thousands, and some are relatively toxic. The principal VOCs produced by combustion engines are polycyclic aromatic hydrocarbons (PAHs) that form in almost all types of incomplete combustion and contain several carcinogenic components like benzo[a]pyrene (BaP); oxygenated hydrocarbons including aldehydes (e.g.: formaldehyde), cetones (acetone), alcohols (e.g.: methanol) and organic acids (formic acid) are all respiratory tract and mucous membrane irritants. Some VOCs, including benzene, chloroform and formaldehyde, are considered carcinogenic.

The photochemical reaction of NO_x with VOCs forms secondary pollutants collectively known as photochemical smog. This smog includes ozone (O_3) on the ground (tropospheric), various free radicals, oxygenated hydrocarbons like aldehydes, and peroxyacetyl nitrates (PAN). All can be respiratory irritants, and some are mutagenic (PAN) or carcinogenic (formaldehyde). Smog is a concern because of the health problems it causes and because it is an urban atmospheric pollutant that is on the rise in Canada.

In the Pearson Airport impact study most of these pollutants originate outside the airport zone. This airport is located in one of the most densely urbanized and industrialized regions of Canada, however; in a rural context, the main source of local atmospheric pollution would probably be the airport itself. In future years, high-performance aircraft with modern engines will cause less pollution. The study notes that with more runways, idling time is reduced, reducing pollution as well.

Pollution and disturbance of the aquatic environment

The two problems here are permanent physical construction disturbances and chemical pollution.

Runway construction can impact significantly on the aquatic milieu. The diversion of streams and draining alters morphology and destroys aquatic habitats. Expansion of asphalt surfaces increases runoff toward water bodies, increasing suspended matter and sedimentation and disturbing fish habitats, especially during critical spawning periods.

Chemical water pollution is caused by products used for plane and runway de-icing and for runway cleaning. Liquids used during firefighter training exercises are potential pollutants, but are normally contained within a specific perimeter.

Plane de-icing liquids

Wing de-icing is necessary in the winter, particularly under freezing rain conditions, and as a preventive measure to prevent ice build-up on the wings when increasing altitude. A hot solution of ethylene glycol or propylene glycol is sprayed on the wings. The solution may also contain phosphate-based anti-corrosives and wetting or thickening agents to facilitate adhesion.

Ethylene glycol ($C_2H_6O_2$) is commonly used in antifreeze. It is a highly toxic water-miscible substance, that is lethal at a proportion of 1.4 mg/kg; the ingestion of 100 ml of pure ethylene glycol can kill an average adult. Intoxication symptoms are vomiting, dizziness, respiratory difficulty and convulsions. Renal damage causing uremia and anuria is fatal. .Unlike ethylene glycol, propylene glycol ($C_3H_8O_2$) has a low toxicity since it is oxidized in pyruvic and acetic acids. Even so, lab studies show an LD_{50} (lethal dose) of 25ml/kg in rats.

More than half of the de-icing solution runs off the wings and into the local sewer system or open drainage ditches. Glycol solutions are the most significant aquatic airport pollutant. They impact harmfully on aquatic fauna, since glycol is a major organic pollutant with a high biological oxygen demand (BOD); it stimulates bacterial growth, reducing the quantity of oxygen dissolved in the water. Fish suffocate for lack of dissolved oxygen and unpleasant odours are created through excessive bacteria proliferation. The phosphates contained in certain de-icing solutions stimulate the growth of aquatic vegetation, especially algae, and cause eutrophication in receiving waters, creating conditions unfit for aquatic life and degrading recreational zones.

Runway de-icing

Runway de-icing is necessary to ensure safe take-off and landing. Most airports use sand as an abrasive and urea as an ice-melter. Pearson uses an average of 7 tons of abrasive and melters per de-icing operation, a dozen times a year. The airport is in one of the mildest climate zones of Canada; use would be higher in more northerly airports.

The abrasive helps prevent skidding, particularly at very low temperatures where ice melters are less effective. Abrasives increase the level of suspended solids (SS) in water, disturbing aquatic life, increasing turbidity and silting up watercourses.

A urea solution is used rather than traditional ice melters like sodium chloride (NaCl) and calcium chloride ($CaCl_2$), which are too corrosive and could cause operating problems. The problem here, however, is that urea transforms into ammonia (NH_3), and into nitrites and nitrates.

Ammonia (NH_3) dissolved in water is highly toxic, but under generally existing pH conditions inferior to 8.0, almost always occurs as the much less toxic ammonium ion (NH_4. In concentrations higher than 0.5 mg/L (the standard for drinking water samples), ammonia reduces chlorination effectiveness. Nitrites (NO_2 ion) are highly toxic and can form methemoglobin, which prevents the transportation of oxygen in the blood. Nitrites can also bond with organic molecules to form carcinogenic nitrosamines. However, they are very instable and transform rapidly into nitrates. Nitrates are the principal nitrogenous form found in natural waters, since the nitrate ion (NO_3^-) is very soluble and very stable. The main environmental impact is eutrophication. Ingesting water containing more than 10 mg/L of nitrates can in the long term cause methemoglobin formation.

Runway degumming

During landing, the weight and speed of the plane exert enormous wheel pressure and rubber is left on runways, which must be degummed once or twice a year to maintain friction and prevent skidding. Pearson sprays a solution of sodium hydroxide (NaOH) and sodium metabisulfite ($Na_2O_5S_2$) on the runway to swell and soak off the rubber, which is then removed with powerful water jets. The solution and rubber particles are washed off the runway, and no particular measures are employed for their collection. Some of the solution disappears through evaporation. While a Transport Canada study did not find the solution toxic, NaOH in solution is highly corrosive. Sodium metabisulfite has a very low toxicity, and is used in some pharmaceutical compounds.

Health effects of water pollution

The principal aquatic pollutants associated with terminal operations are not likely to cause immediate public health problems. Most of these pollutants normally run into drainage canals or sewer systems. The main substances used (glycol, phosphate, nitrogen) are not persistent toxic compounds that bioaccumulate in the food chain. For esthetic and ecosystem purposes, however, their contributions to microorganism proliferation eutrophication must be considered.

Waste production and land pollution

This section covers loss of land fauna habitats, site contamination and waste production.

Airport zones take up vast areas, large parts of which are devoid of any human activity. However, several animal species inhabit the perimeters: 96 bird species and 11 mammal species were counted at Pearson. In many ways, restricted human access makes urban airports virtual animal sanctuaries. Runway construction or expansion destroys part of the land habitats, although paved or non-natural surfaces generally make up a small proportion of the perimeter (usually less than 15%). Fauna cannot move freely, however, since in most cases habitats are manipulated, animals are trapped or scaring techniques are used to chase birds off take-off zones.

De-icing liquids and fuel can also contaminate the ground. Underground fuel reservoirs are a risk and their watertightness must be checked at regular intervals. Contamination by oil spills or more toxic substances like polychlorinated biphenyls (PCBs) was found in a number of airports. Sites under federal jurisdiction must be decontaminated, and airports under provincial or municipal jurisdiction must be checked on a case-by-case basis for contaminated soil.

The domestic waste generated by normal airport operations is primarily paper or plastic restaurant garbage. Waste production rises significantly during the construction of new buildings or runways, with sand, gravel, wood and a variety of debris added to the mix. About 60% of domestic waste is recyclable. Restaurant garbage can be composted, while paper and plastics can be recovered and recycled. Larger trash like tires should also be recycled. Under the 1990 federal plan, most provinces aim to reduce solid waste by 50%. In exceptional cases (especially in the far north), landfill sites can be located on or near the airport. They must guard against water and soil pollution (by percolation and leaching), air pollution (windborne objects and particles) and vermin.

Waste contained inside planes is considered international waste. Under Agriculture Canada, Health Canada and Transport Canada regulations, it cannot be mixed with waste from ground operations, and must be contained and incinerated as soon as it leaves the plane. Because this waste management and the related costs are the responsibility of the carriers, they may choose to return it to its place of origin (where the materials were prepared).

Contaminated sites and domestic waste production are not particular public health risks; unprotected landfill sites in isolated northern regions are the only real risk.

Noise and psychological and social impacts

Noise is the major public health environmental nuisance. Noise is generally defined as any acoustic energy likely to alter physical or psychological well-being. The standard measure is the mean value of equivalent noise level (L_{eq}) per time unit (24 hours, for example). It is measured using the decibel scale, a logarithmic scale, meaning that noise doubles in intensity with each increase of 3 decibels.

The World Health Organization (WHO) proposes an indoor residential limit of less than 45 dB(A) during the day and 35 dB(A) at night. Its outdoor daytime limit is 50 dB(A) L_{eq} and 45 dB(A) L_{eq} at night. Over 55 dB(A), the nuisance level in a residential neighbourhood is considered serious. In industrial zones or work environments, a level of 75 dB(A) L_{eq} (8 hours) is considered acceptable. These standards are currently under review.

The main problems of noise are loss of sleep, communication problems, effects on the performance and behaviour of students and a feeling of decreased quality of life. Chronic exposure can cause increased blood pressure.

Close to Pearson Airport, outdoor average noise intensity varies from 60 to 80 dBA during the day and from 50 to 70 dBA at night. During intense flight activity, peaks of 100 dBA have been recorded. Outdoor activities are affected when planes fly over residential areas. The study finds that the noise levels will not cause physical problems like hearing loss, and that nocturnal indoor levels should not disturb sleep. However, there is no mention of follow-up studies on long-term psychological or psychiatric problems. The new generation of turbojet engines are much quieter, so in the coming years noise pollution should decrease despite increased air traffic.

Reduced property values in the vicinity of airports are a common concern, and resale prices may be lowered.

Sector: Transportation Activity: Airport Construction/Operation

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological Disaster	plane crash	- destruction, pollution from toxic smoke and liquids	-site and perimeter of crash	- covering, confinement, containment	
Gaseous or air emissions	- CO	- negligible	- local and regional	- combustion control	- 35 mg/m^3 (1h)
	- CO_2	- greenhouse effect	- global	- reduce fossil fuels	- none
	- NO_x	- toxicity, smog formation	-regional and continental	- antipollution systems	- 200 μg/m^3 (24h) for NO_2
	- VOC	- toxicity, smog formation	- regional and continental	-containment or ↑ combustion performances	- none
	- suspended particulates	-deposited on vegetation, buildings, unattractive appearance	- local and regional	- containment or filtration	- 120 μg/m^3 (24h)
Liquid emissions or discharge into water	- diversion and drainage of waterways	- destruction of wildlife habitats	- onsite waterways	- mitigation measures	- Fisheries Act
	- suspended solids	- disturbance of aquatic fauna	- onsite waterways	- mitigation measures	- Fisheries Act
	- ethylene or propylene glycol	- organic pollution, oxygen deficiency	- onsite waterways	- containment	- BOD_5 of 20 mg/L
	- urea	- pollution, eutrophication	- onsite waterways	- containment	- no federal standard
	- sodium hydroxide (NaOH)	-alkalinization, toxicity	- onsite waterways	- containment, neutralization	- alkalinity variation limited to 25% of the natural concentration
Solid emissions or discharge into soil	- domestic waste	- appearance, environmental health, vermin	- site and perimeter	- collection, recycling, sanitary landfill	- municipal by-laws
	- international waste	- foreign parasites and micro-organisms	- N.A.	- incineration required	-international agreements (Agriculture, Health and Transport Canada)
	-dangerous waste (petroleum, PCB, etc.)	- toxicity, unsanitary	- site and perimeter	- confinement, elimination through appropriate procedures	- Canadian Environmental Protection Act
Nuisances	- noise	- N.A.	- local	-establish buffer zones, use new generation aircraft, prohibit night flights	- L_{eq} 45 dBA at night and 55 dBA during day (WHO standards); Canadian Environmental Assessment Act
Indirect impacts or other exposures	-social conflict, property devaluation and degradation	- economic	- local	- financial compensation limit flights	- N.A.

STRESSOR/ EXPOSURE	Effect on Health	Population at Risk	Probability of Occurrence	Environmental/ Biological Indicator (Monitoring)	Information/ References
Technological Disaster	- trauma, injury, death	- plane passengers and ground population	- rare	- mortality and morbidity ratios, Transportation Safety Board	- consult Transportation Safety Board (Ottawa)
Gaseous or air emissions	- ↑ in % of carboxyhemoglobin, death	- local residents	- very rare	- % of carboxyhemoglobin	
	- climatic changes	- global population	- frequent	- measure in ambient air	
	- irritation of respiratory tracts	- urban zone residents	- occasional during summer period	- measure in air, epidemiological studies	
	- irritation of respiratory tracts, smog provoking inflammation	- urban zone residents	- occasional during summer period	- measure in air, epidemiological studies	
	- various respiratory problems	- urban zone residents	- rare	- measure in ambient air	
Liquid emissions or discharge into water	- N.A.	- N.A.	-N.A.	- state of fish population	
	- N.A.	- N.A.	- N.A.	- state of fish population	
	- toxic if ingested (lethal dose: 1.4 mL/kg for ethylene glycol)	- none	- N.A.	- proportion in waterways or sewers	
	-toxic if ingested or methemoglobin	-none	- N.A.	- proportion in waterways or sewers	
	- toxic if ingested	- none	- N.A.	- pH measure	
Solid emissions or discharge into soil	- hygiene and health problems	- airport users and peripheral residents	- rare to moderate	- public complaints	
	- propagation of exotic diseases	- plane passengers	-unknown	- complaints, medical follow-up after incidents	
	- toxic and potentially carcinogenic effects	- airport workers	- rare	- medical follow-up of workers	
Nuisances	- quality of life, sleep disturbances, stress, aggressiveness, hypertension	- residents of airport periphery	- rare to frequent	- measure of internal and external ambient noise	

Indirect impacts or other exposures	- individual and group stress	-neighbouring community	- occasional	- property assessment follow-up, perception studies	

References

Budavari, S., M.J. O'Neil, A. Smith and P.E. Heckelman, editors, (1989) The Merck Index. Eleventh edition, Merk & Co. New Jersey, USA, 1606p. + appendices.

Lajoie, P. (1997) Particules dans l'atmosphère: des normes plus sévères pour protéger la santé. Bulletin d'information en santé environnementale (BISE), 8(3): 1-4.

Lévesque, B. and D. Gauvin (1996) Le bruit communautaire. Bulletin d'information en santé environnementale (BISE), 7(1): 4-6.

Transport Canada (1991) Lester B. Pearson International Airport, Airside Development Project: environmental impact statement summary. Department of Transport, Government du Canada,TP Report 10675E, 33p.

Transport Canada Airports (1991) Lester B Pearson International Airport Environmental Management Plan. Department of Transport, Government du Canada, TP Report 10678E, various pagings.

See also the texts and references of the following grids:

- Roads and highways (for atmospheric pollutants);
- Sanitary landfill (for pollution caused by domestic waste).

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 5 of 11

Forests

Canadian outlook

Canada has approximately 418 million hectares of forests, representing 42% of its total area. Of that, 245 million ha can produce merchantable timber. The timber forest is formed of about 63% softwood conifer stands, 15% deciduous forest and 22% composite forest. Provincial governments manage 71% of the country's forests, while the federal and territorial governments manage 23%. The remaining 6% are private forests belonging to more than 425,000 owners.

In 1993, the lumber and paper industry contributed $19.8 billion to Canada's GDP, 40% of which was attributable to the pulp and paper sector. It was the forest sector that generated the most foreign currency revenues, contributing $28 billion to the trade balance. The logging industry provided direct employment for nearly 370,000 people in 1994.

Quebec forests

Quebec can be divided into three major vegetation zones: the tundra north of the 55th parallel; the taiga comprising black spruce stands dispersed over a lichen mat between the 52nd and 55th parallel, and the forest south of the 52nd parallel. This last zone, covering 757,900 km^2, is commercially exploited. It is divided into three more zones: the boreal coniferous forest in the north (belonging almost entirely to the Quebec government); the composite deciduous and coniferous forest in the centre, and the southern deciduous forest located primarily in the St. Lawrence Plain, the Outaouais and Témiscamingue.

Although most of the deciduous forest located in the south of the province belongs to private owners, the boreal forest comprising 73% of the timber forest is so vast that the Quebec government actually owns 85% of the total forest area. Given this fact, the government has assumed the mandate of implementing various measures aimed at protecting the timber forest against fire, destructive insects and competing vegetation, while ensuring its renewal and accessibility for diverse activities.

The forest is a source of intense economic activity, as more than 30 million m^3 of wood material is harvested annually. This volume is equivalent to 460,000 trucks 45 feet long hauling 65 m^3 of average-size non-debarked logs. In 1994, had the logs on about 76 of these trucks been lined up end to end, they would have made a chain about 6,000 kilometres long, comparable to the breadth of Canada (± 7,775 km from St. John's, Newfoundland, to Victoria, British Columbia). That same year, 76,000 people, or 2.4% of the Quebec labour force, were employed in jobs directly related to logging or the lumber and paper industries. The 1994 monetary value of logging industry deliveries (forest harvesting, lumber processing and the pulp and paper industry) was $15.5 billion. In 1994, there were 62 pulp and paper mills and one thousand lumber mills.

References

Canada (1996) *The State of Canada's Forests, 1995-1996.* Forestry Department, Natural Resources Canada, Government of Canada, 112p.

Canada (1996) *The State of Canada's Environment.* Government of Canada, 820p.

Parent, B. (1996) *Ressources et industrie forestières; portrait statistique de 1996.* Ministère des Ressources Naturelles, Government of Quebec, 142 p.

Phytocide utilization for forest clearing and regeneration

In forestry, the term phytocide has the same meaning as the term herbicide in agriculture and the same product may be sold under a different brand name for either use.

Uses of phytocides

Phytocides are usually used after logging to ensure the regeneration of young conifers that grow relatively slowly and face competition from competing or lesser vegetation. The latter group comprises pioneer species that grow rapidly in distressed areas (after logging, destructive forest fires, wind, snow or insect pests). They can hinder the growth of the young, natural or planted trees by blocking light, absorbing water and nutritive elements and taking up a lot of space. While these species are not harmful, they are opportunistic. They include fireweed, wild raspberry, grasses, white birch and hoary alder, which develop quickly.

There is a whole variety of approaches and techniques for limiting the use of mechanical or chemical control of competing vegetation. They are grouped according to their mode of action: biological (grazing organisms in pasture); biomechanical (e.g., mulching to inhibit the growth of competing vegetation); mechanical, and phytocidal (using chemical products to control vegetation growth). As a general rule, clearing is done mechanically using various tools to cut the competing vegetation (motorized or Handbook scythes, bush knives, circular saws, etc.), or chemically with phytocides.

The ultimate goal of these techniques is to protect regeneration in a such way that the young conifers can develop normally under ideal conditions without human intervention.

Competing vegetation is not destroyed mechanically or chemically at all logging sites. This practice is reserved for areas where it is necessary to plant new trees by hand and, in 1996, this represented only 15% of the areas under regeneration. Moreover, 25% of the transplant areas were not treated. Therefore, the 75% of transplanted treated areas corresponded to only 11% of the entire area under regeneration (75% of 15%). The largest areas treated with phytocides are generally in the regions of the lower St. Lawrence (5,715 hectares of mostly public forest, in 1996) and Quebec (2,000 hectares of strictly private forest).

Phytocide application can be carried out using spraying equipment mounted on airplanes or helicopters. It may also be applied at ground level by heavy machinery or by humans using portable motorized or Handbook spraying devices. When motorized ground spraying is carried out, the environmental and worker health impacts of combustion gases must also be considered.

Treated area

From 1984 to 1993, the total Quebec forest area treated with phytocides increased from 3,500 hectares to more than 27,000 (78% public forest and the balance private). However, treated areas have been steadily decreasing since 1993. Predictions for 1997 were 20,935 ha including 14,460 ha of public forest, or 50% of the area treated in 1993. In its 1994 Forest Protection Strategy, the government also announced its intention to abandon the use of phytocides in 2001, and espouse a whole series of preventive techniques to protect and assist regeneration. However, since this is not a ban on forest applications of herbicides, private forest owners may continue to use phytocides beyond this date if they wish.

The nature of glyphosate and how it works

Currently, glyphosate (respectively known as "Roundup" and "Vision" in the agricultural and forest milieus) is about the only phytocide in use. Developed in the 1960s, glyphosate is a non-selective phytocide effective against herbaceous plants, brush and trees. It is an essential aromatic amino acid synthesis inhibitor that alters the plant's metabolism and causes death. As a non-volatile product, it is only temporarily airborne as droplets during spraying. Natural environmental microorganisms break it down rapidly into aminomethylphosphoric acid (AMPA) which then splits into phosphates and CO_2. Its half-life is less than two months and it is undetectable after 12 to 15 months. The active ingredient is applied at a rate of 1.5 kg per hectare. In the days following application, foliage residues average 500 µg/g (wet weight) and the maximum average contamination of fruit such as raspberries is 33 µg/g (fresh weight).

Effects on humans

In humans, the amount of glyphosate titrated in the urine is directly proportional to exposure. Contamination can occur by any means including ingestion, inhalation, and absorption through the skin. According to the Centre de toxicologie du Québec models, a person living near the site would receive a daily dose of about 0.0004 mg/kg and the dose for people fishing or hunting in a recently-treated area would be 0.0006 mg/kg. But this dose is less than the 0.023 mg/kg that the adult population ingests when consuming cereals and beer. The EPA suggests that the acceptable daily intake is around 0.1 mg/kg. No teratogenic, mutagenic or carcinogenic effects attributable to chronic exposure to glyphosate have been detected.

Environmental effects

All the data and information collated by different organizations indicate that glyphosate has few notable environmental effects. When it is sprayed after the middle of August, it has no effect on the desired coniferous growth because this is the time the conifer buds begin their winter dormancy period and the trees will not metabolize the glyphosate. The metabolism in young deciduous trees, however, is still active, making them vulnerable to glyphosate.

Low concentrations of glyphosate can be found in water and soil after spraying. It is quickly immobilized on soil particles where it is broken down primarily by the existing natural microorganisms. Although deciduous defoliation may alter herbivorous browsing patterns, animals and birds are not affected by glyphosate. Normalcy returns after a few years when the deciduous trees start to grow again. It should be noted that only one spraying is required per sector to enable the conifers to dominate competing vegetation naturally.

Sector: Forest
Activity: Phytocide (glyphosate[11]) Spraying to Promote Forest Regeneration[12]

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster					
Gaseous or atmospheric emissions	- glyphosate	- deciduous defoliation - possibility of slight change in nesting bird populations - air pollution	- site and perimeter - site and perimeter - site and perimeter	- limit drift by accommodating wind speed, direction, humidity	- none
	- combustion gases			- none	- CO: 0.3 ppm (1h), 0.13 ppm (8h), Q-2 atmosph. qual. reg. - benzene: 30 mg/m^3 - formaldehyde: 3 mg/m^3 (QC work standards)
Liquid or waterborne emissions	- glyphosate	contamination of captor aquatic environment CL$_{50}$: 1.3 mg/L (most sensitive species: rainbow trout)	- site and perimeter	- buffer strip: 60 m for aerial spraying, 30 m for ground spraying	- MEF and EC raw water criteria: 0.28mg/L - 0.1 mg/kg/d (EPA)
Solid or soil-borne emissions	- glyphosate	soil contamination: microorganisms are primary means of breakdown	-site (glyphosate immobilized in soil)	- none	-none
Disamenities	- noise (motors)	- salubrity - salubrity	- site, perimeter and vicinity - site	- motor mufflers - filters	- L$_{eq}$: 50 dB (day)
	- vibrations				
	- odours (gasoline and phytocide)				
Indirect impacts or other exposure	- phytocide spill	- soil and watercourse contamination	- spill site	- preventive measures, training	- Q-2, section IV

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[11] Glyphosate is the herbicide used almost exclusively by the ministère des Ressources naturelles du Québec (MRN) and private, government-subsidized producers.

[12] This grid is valid for public and private forest spraying done according to MRN guidelines. It does not apply to Hydro-Québec spraying practices in their rights-of-way or to the agricultural use of glyphosate (Roundup®).

	- social conflict	- economic value	- vicinity	- communication	
	- crash of craft used for spraying	- destruction, contamination	- crash site and immediate perimeter	- recovery of spilled substances	

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biol./Environmental Monitoring Indicators	Information/ References
Technological disaster					
Gaseous or atmospheric emissions	- no remarkable effects	- N.A.	- N.A.	- N.A.	BAPE (1997) Couture *et al* (1995) MRN (1995)
	- CO: carboxy-hemoglobinemia - formaldehyde and NO_x: resp. irritations - benzene and PAH: cancers	- workers, mostly those doing ground-level spraying with motorized machines	- unknown - unknown - unknown	- blood CO concentration - symptoms, medical follow-up - epidemiological studies	
Liquid or waterborne emissions	- no remarkable effects at concentrations found in the environment	- N.A.	- N.A.	- conduct fish toxicity tests (determine CL_{50})	- same as above plus Dostie (1991) EXTOXNET (see Internet reference)
Solid or soil-borne emissions	- no effect	- N.A.	- N.A.	- N.A.	same as item on "gaseous emissions"; Legris and Couture (1992)
Disamenities	- quality of life	- mostly workers	- frequent	- complaints	MRN report (see above)
	- quality of life	- workers	- frequent	- complaints	
	- quality of life	- workers and vicinity	- occasional to frequent	- complaints	
Indirect impacts or other exposure	- nausea and vomiting; NOEL: 175 mg/kg/d	- workers	- very rare	- medical follow-up	
	- quality of life/stress	- vicinity, community	- rare to occasional	-complaints/ perception	
	- injuries/death	- pilot	- very rare	- public safety	

References

BAPE (1997) *Programme de dégagement de la régénération forestière*. Bureau d'audiences publiques sur l'environnement, Government of Quebec, 133p.

Couture, G., J. Legris and R. Langevin (1995) *Évaluation des impacts du glyphosate utilisé dans le milieu forestier* (Appendix E of the *Étude comparative des modes de dégagement de la régénération forestière*). Ministère des Ressources naturelles, Government of Quebec, 187p.

Dostie, R. (1991) *Dépôt du glyphosate à l'extérieur des aires traitées par voie terrestre en 1989*. Ministère des Forêts, Government of Quebec, 14p.

Legris, J., G. Couture (1992) *Résidus de glyphosate dans les fruits sauvages à la suite de pulvérisations terrestres en milieu forestier en 1989 et 1990*. Ministère des Forêts, Government of Quebec, 25p.

MRN (1994) *Une stratégie: aménager pour mieux protéger les forêts*. Ministère des Ressources Naturelles, Government of Quebec, 195p.

MRN (1995) *Étude comparative des modes de dégagement de la régénération forestière, Main Report, Volume 2*. Ministère des Ressources Naturelles, Government of Quebec, p.

Use of *Bacillus thuringiensis (B.t.)* Insecticide

The microbial insecticide *Bacillus thuringiensis* (*B.t.*) is widely used in forests to combat certain destructive insects, notably the spruce budworm[13] and, since 1987, it has been the only product authorized for aerial spraying against the budworm in Quebec. Since the beginning of the 1990s, many Quebec municipalities also use *B.t.* to control a variety of biting insects (mosquitos, blackflies, etc.) that present a real nuisance.

The spruce budworm: Canadian and Quebec outlook

The lepidoptorous spruce budworm causes serious damage in coniferous forests throughout the entire country, from Yukon to Newfoundland. Infestations occur on an average of every 30 years and sweep through Canada from west to east. It attacks mainly balsam fir and white spruce. During the 1940 and 1950 infestations in Quebec, the respective mortality in these trees was 65% and 20%.

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[13] In spite of the insect's name, the most vulnerable conifer is the balsam fir.

The budworm is the most destructive parasite in Eastern Canada. As an integral part of the ecosystem for the last 10,000 years, this insect has occasionally helped create new stands by accelerating the decline of old-growth forests. But, when humans began to exploit forests commercially, the situation changed. The first recorded evidence of this insect dates back to 1704. From then until the end of the 19th century, there have been half a dozen infestations lasting up to 10 years each. A major epidemic in Eastern Canada in the 1920s did so much damage in New Brunswick that some companies went bankrupt.

The frequency and duration of infestations increased during the 20th century. By 1975, the last epidemic, starting in Quebec's Outaouais region in 1968, had spread to the entire coniferous forest territory, infesting an area of 35 million hectares. Although the epidemic had ended by 1987, some residual pockets of infestation were found in the Gaspé Peninsula. The losses from this epidemic were estimated at approximately 235 million m^3 of wood.

Biting insects

Biting insects, particularly mosquitos and blackflies, are a nuisance for humans and, to a lesser extent, for domestic and wild animals. Essentially, they make many people's lives so miserable that outdoor activities must be curtailed from the beginning of June until the end of July, during the time when the insects are most active. These insects can thus be economically detrimental to tourism. Unlike those in the tropics and certain regions of the United States, biting insects in Canada are not carriers of diseases such as encephalitis. From the public health perspective, they are considered more of a nuisance than a genuine problem.

Insecticides used in Canada before *B.t.*

The first intensive aerial spraying against the budworm was carried out in New Brunswick and eastern Quebec in the 1950s. Until 1962, the only pesticide used was DDT. When DDT was banned in the early 1970s, organophosphorous fenitrothion, aminocarb and mexacarbate (two carbamates) were used from 1974 to 1976. Mexacarbate was withdrawn in 1977 and *B.t.* was used for the first time in 1978. The scenario was similar in 1982 and 1983 except that the use of *B.t.* increased. In 1987, *Bacillus thuringiensis* became the only insecticide to be used in Quebec forestry for controlling the spruce budworm. After 1990, attempts were also made use *B.t.* to control other destructive forest insects such as the hemlock looper, the jack pine budworm and the Swaine jack pine sawfly.

Basic information on *Bacillus thuringiensis*

B.t. is a rod-shaped aerobic bacteria found everywhere in the world. Although it was discovered in Japan at the turn of the century, it wasn't until the 1920s that its insecticidal property was recognized. There are 34 *B.t.* sub-species (serotypes and varieties) and about 40,000 strains. The strain most commonly used in Canada for aerial forest spraying is *Bacillus thuringiensis* var. *Kurstaki* (*B.t.K.*). The strain used to control biting insects in urban and tourism areas is *B.t. israelensis* (*B.t.i.*). For this use, it is injected into the water to control the mosquito larvae rather than being applied by aerial spraying. There are 17 commercial *B.t.K.* preparations on the Canadian market for controlling lepidoptera. Although this variety is primarily used in Quebec to control the spruce budworm, its use is now spreading into agriculture.

Mode of action

The insecticide preparations contain the endospore of the bacillus and the crystal, a parasporal body. When the latter is dissolved in the alkaline digestive tract of certain insect larvae, it releases a variety of proteins called protoxins or delta- endotoxins. Specific enzymes in the digestive tract transform these d-endotoxins into active toxins that alter the intestinal cellular structure, precipitating epithelial perforation and an osmotic imbalance. Within minutes of ingesting these crystals, larval nutrition ceases and death occurs within a few hours. It must be specified that for the crystal to dissolve, the pH of the medium must be alkaline, i.e., between 9 and 11. Also, the various toxins are quite selective and their action spectrum is limited to certain groups of insects.

Environmental mobility and persistence of *B.t.*

B.t. spore dispersion in the air is obviously a factor of wind direction and speed, the level of humidity and the size of the insecticide particles at the time of spraying. The level of *B.t.* spore concentration in the air decreases rapidly since less than 2% of the total concentration can be detected 2 hours after dusting. Most samples taken in municipalities located close to treated sectors showed bacterial concentrations of less than 1 cfu/m^3 [14]. However, the presence of spores in the ambient air several months after spraying indicates some environmental persistence.

Although not necessarily viable, *B.t.K.* spores can persist on vegetation for up to a year. Viable spores have been found a month after spraying. Protection from ultraviolet solar rays may explain the persistence of viable spores on plants. Spores found in splits and folds of foliage, cones or rough tree bark are not exposed to UV rays and thus have greater longevity.

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[14] Cfu, colony-forming unit: in theory, each viable spore and each vegetative bacterial cell placed on a nutrient agar (in a Petri dish) should form a visible colony after a few hours or days. In this context, it signifies one bacterium per cubic metre of air.

Environmental persistence of *B.t.K.* in water follows a pattern similar to that observed in the air. Concentrations decline rapidly within the first hours and medium-term concentrations (several months to a year) are very low (less than 1% of the highest levels recorded in the first few hours). Although the medium-term aquatic persistence of *B.t.* is primarily due to soil leaching by rainwater and snow-melt runoff, most of the *B.t.* is found in sediment after it has been in the water for a few weeks.

B.t.K. is most persistent in the soil where it can remain for up to seven years. One study showed that spore and crystal breakdown is non-existent or minimal after more than 8 weeks in forest and agricultural soils. Another observed that the concentration of microorganisms remained constant a year after spraying. It is noteworthy that the vertical percolation of *B.t.* into the soil is minimal. Since 90 to 99% of the spores remain within the top five centimetres, there is very little chance the *B.t.K.* would reach ground water aquifers. Moreover, studies have shown there is little likelihood of the spores germinating in acid soils and this is the type of soil found beneath the boreal coniferous forest where most of the spraying is done.

Effects of *B.t.* on animals and humans

Experimental oral, respiratory, subcutaneous and ocular exposure of mammals to *B.t.* produced no adverse effects even though *B.t.K.* was observed in all the intestinal flora of the workers and students three months after the spraying period. It appears that the bacillus can be spread from person to person or through indirect contact with clothing or air.

Some mention has been made of the bacillus possibly acting as an opportunistic agent in aggravating disease, or as a co-pathogenic or synergistic agent. There is, however, little information on the subject and the role of *B.t.* in the few documented cases was minor.

B.t. is also known to persist in the blood and digestive systems as well as in a variety of organs including the eyes, nose, lungs, liver, spleen, kidneys and brain. Depending on the organ affected and the initial bacterial concentration, this persistence may last a few hours or several months. The formation of IgM, and later, IgC, antibodies has been observed. These immunological reactions are caused primarily by the presence of vegetative cells rather than the presence of spores or crystals. The antibodies last only a few months and no health problems were detected in the workers or other people who developed them.

Towards the end of the 1980s, an extensive epidemiological study conducted in a region of Oregon with a population of 120,000 (where *B.t.K.* was used to control the Asiatic gypsy moth), brought to light 3 cases in which the role of the bacillus was unclear. The three people in question had immuno-suppressive health problems well before the spraying. In all three cases, however, it was impossible either to attribute infectious problems to *B.t.K.* or to exclude the bacillus's etiological role with any certainty.

In the mid-1990s, some strains of *Bacillus thuringiensis* were found to produce a diarrhoeal enterotoxin capable of causing food poisoning. The authors of the study also identified a strain of *B. thuringiensis* var. *Kurstaki* in several foods of plant origin, the implication being that the micrioorganisms could be ingested. The presence of *B. thuringiensis* was reported in several of the food poisoning victims in an outbreak at a seniors residence, but it was impossible to specify what etiological role the *B.t.* played. Reports from Italy indicated *B. thuringiensis* was also isolated from some severe burn wounds. It is important to specify that, in all these cases, elaborate characterizations were necessary to differentiate *B. thuringiensis* from *B. cereus*, both of which are genetically close. Since *B. cereus* is well known for its role in many infections, and particularly gastroenteritis, the importance of differentiation is understandable. However, the studies were inconclusive as to the exact etiological role of *B. thuringiensis*.

Finally, cutaneous provocation tests brought to light no allergic reactions on unbroken skin and there have been no reports of cases of mutagencity associated with the presence of *B.t.*

It is therefore reasonable to conclude that *B. thuringiensis* represents no risk to the majority of healthy people. Nevertheless, the possibility of opportunistic infection in people with immunodeficiencies or serious infections cannot be ignored. It is also important to remember *B.t.K.* is not the strain used for controlling biting insects; *B.t.i.* is used instead and application in this instance is not by aerial spraying.

Effects of *B.t.* preparation additives

Commercial *B.t.* preparations basically contain the toxin crystals, spores and cellular debris to which various substances are added, the majority of which are the water or oils used to suspend the spores and toxins. Next, additives intended to increase the insecticide's effectiveness are added to the suspension. These additives are diluents (water, oil, powdered clay), emulsifiers, thickeners, humectants, foam inhibitors, substances that encourage the insects to eat the crystals (such as sugar), and stabilizing agents (antioxidants, antibacterials, evaporation suppressants). It must be specified that since the nature and chemical composition of these additives are protected trade secrets, it is impossible to know the exact potential toxicity of commercial *B.t.* preparations.

However, we do have enough information to state that some of these additives have slightly irritating properties, as confirmed by the warnings contained on commercial product data sheets. The organs most sensitive to additives are the respiratory system and the eyes. Eye irritations and conjunctival congestion observed in rabbits are caused by the abrasive properties of the additives. A case of corneal ulceration, diagnosed in a man who splashed insecticide into his eye, was also caused by the additives. Finally, the higher frequency of eye, nose and throat irritation, chapped lips and dry skin in workers exposed to *B.t.K.*, as compared to a control group, could be a response to the presence of products other than the bacteria. In addition, the symptoms of irritation were observed more in workers with a prior history of allergies (asthma, eczema, seasonal allergies).

Sector: Forest

Activity: *B.t.* (*Bacillus thuringiensis*) spraying to control certain destructive forest insects and urban biting insects

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster					
Gaseous or atmospheric emissions	- B.t. spores and crystals	- residue on plants; no known toxic effect	- site, perimeter and vicinity	- limit drifting	- no standards
	- various additives	- air pollution	- site, perimeter and vicinity	during spraying - limit drifting during spraying	- commercial B.t. preparations subject to federal pesticide registration process
Liquid or waterborne emissions	- B.t. spores and crystals	- presence and persistence in surface water	- site, perimeter and vicinity	- avoid passing over water-courses and expanses	- stop spraying near shorelines (cut edges), no other standard
	- various additives	- unknown	- unknown	- idem	
Solid or soil-borne emissions	- B.t. spores and crystals	- presence and persistence in soil	- site and perimeter	- none practical	- none
	- various additives	- unknown	- unknown	- none practical	- none
Disamenities					
Indirect impacts or other exposure	- concentrated insecticide solution spill	- soil and watercourse contamination	- spill site	- preventive measures, worker training	
	- crash of the spraying aircraft	- destruction, contamination	- crash site and immediate vicinity	- recovery of spilled substances	
	- social conflict	- economic value	- vicinity	- communication	

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biol./Environmental Monitoring Indicators	Information/ References
Technological disaster					
Gaseous or atmospheric emissions	- probably none, opportunistic infections in the immunodeficient	- immunodeficient(?)	- unknown or very rare	- viable spore counts (cfu)[15]; epidemiological studies	Lessard and Bolduc (1996) Damgaard *et al* (1995 1996, 1997) Green *et al* (1990)
	- possible eye, skin and respiratory tract irritations	- exposed workers	- rare	- unknown (additives protected trade secrets)	
Liquid or waterborne emissions	- probably none, opportunistic infections in the immunodeficient	- immunodeficient(?)	- unknown or very rare	- viable spore counts (cfu) in surface and drinking water	Lessard and Bolduc (1996) Damgaard *et al* (1995 1996, 1997)
	- unknown	- unknown	- unknown		
Solid or soil-borne emissions	- unknown	- unknown	- unknown	- N.A.	Lessard and Bolduc (1996)
	- none	- N.A.	- N.A.	- N.A.	
Disamenities					
Indirect impacts or other exposure	- irritations caused by additives	- workers	- rare	- unknown (additives are protected trade secrets)	Lessard and Bolduc (1996)
	- injuries/death	- plane/helicopter pilot	- very rare	- public safety, Transport Canada	Q-2, section IV, impact study on spraying > 600 ha of forest
	- stress, worry	- vicinity, community	- rare to occasional	- complaints/ perception studies	

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[15] It is important to differentiate *B. thuringiensis* from *B. cereus*. The latter is known to cause many types of infections.

References

Damgaard, P.H. (1995) *Diarrhoeal enterotoxin production by strains of* Bacillus thuringiensis *isolated from commercial* Bacillus thuringiensis*-based insecticides*. FEMS Immunology and Medical Microbiology, 12: 245-250.

Damgaard, P.H., P.E. Granum, J. Bresciani, M.V. Torregrossa, J. Eilenberg and L. Valentino (1997) *Characterization of* Bacillus thuringiensis *isolated from infections in burn wounds*. FEMS Immunology and Medical Microbiology, 18: 47-53

Damgaard, P.H., H.D. Larsen, B.N. Hansen, J. Bresciani and K. Jorgensen (1996) *Enterotoxin-producing strains of* Bacillus thuringiensis *isolated from food*. Letters in Applied Microbiology, 23: 146-150.

Dorais, L., M. Auger, M. Pelletier, M. Chabot, C. Bordeleau and J. Cabana (1991) *Pulvérisations aériennes d'insecticides réalisées au Québec de 1974 à 1987 pour lutter contre la tordeuse des bourgeons de l'épinette*. Ministère des Forêts (maintenant ministère des Ressources naturelles), Government of Quebec, unpaginated document.

Green, M., M. Hehmann, R. Sokolow, L.R. Foster, R. Bryant and M. Skeels (1990) *Public health implications of the microbial pesticide* Bacillus thuringiensis*; an epidemiological study, Oregon, 1985-86*. American Journal of Public Health, 80: 848-852.

Jackson, S.G., R.B. Goodbrand, R. Ahmed and S. Kasatiya (1995) Bacillus cereus *and* Bacillus thuringiensis *isolated in a gastroenteritis outbreak investigation*. Letters in Applied Microbiology, 21: 103-105.

Lessard, S. and D.G. Bolduc (1996) *L'insecticide* Bacillus thuringiensis *et la santé publique*. Comité de santé environnementale du Québec, Centre de santé publique du Québec, Beauport, 70p.

MacKay, D. (1987) *Un patrimoine en péril; la crise des forêts canadiennes*. Les Publications du Québec, Government of Quebec, 302p.

Riendeau, R. (1990) *Arrosages aériens: pour les conifères, contre les feuillus*. Forêt Conservation, 57(1): 20-24.

SOPFIM (1992) *Programme quinquennal (1993-1997) de pulvérisations aériennes d'insecticides pour lutter contre certains insectes forestiers. Tome 1, tordeuse des bourgeons de l'épinette, résumé*. Société de protection des forêts contre les insectes et maladies (Government of Quebec), SNC-Lavallin, dossier no. 25255, various numbers of pages.

Van Frankenhuysen, K. (1990) *Development and current status of* Bacillus thuringiensis *for control of defoliating forest insects*. The Forestry Chronicle, October, 498-507.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 6 of 11

Mining

Fundamentals of mining operations in general

Mining operations involve several stages including exploration, removal and processing of the ore[16]. The substances dealt with in mining operations can basically be divided into two groups: metals, which include gold, silver, lead, copper, nickel, zinc, molybdenum and iron, and non-metals, which include asbestos, gypsum, potash, salt, titanium, sulphur, silica and peat. It should be noted that statistics generally include a third group classified as construction or "quarry" materials, which include granite, limestone, marble, sandstone, slate, sand, gravel, lime and cement.

An ore deposit is mined by removing from the ground the minerals and their gangue materials through open-pit mining (surface mining) or underground mining. In open-pit mining, the ore is removed by constant digging and widening of the pit. In Quebec, the best known surface deposits are the asbestos mines of the Thetford Mines and Black Lake region, some of which have a diameter of up to 2 kilometers. In underground mining, the ore is removed by means of vertical shafts and horizontal tunnels which follow the veins or lodes of the materials being mined. Metals such as copper, zinc and gold are generally removed through underground mining operations.

The mined ore must undergo preliminary processing on site to remove most of the gangue. This operation, called mineral dressing, generally involves three stages: preparation, concentration and conditioning. Pollution is produced in varying degrees during these operations, as described below.

Ore preparation consists of crushing the materials so that sizing can be performed. Concentration is the operation whereby the ore pellets (metal or non-metal) are removed from the gangue. The techniques used include gravity (based on the density or weight of the material), magnetic separation and flotation. This latter technique is based on processes whereby the mineral and metal particles are brought to the surface of a liquid. Various chemicals are used to alter the properties of the materials to facilitate their concentration. For example, cyanide is used with gold or silver, whereas copper and zinc are recovered by flotation. Finally, conditioning is the operation whereby the ore is made ready for handling or further metal processing. The purpose of all these operations is to increase the purity of the ore so that it will contain greater concentrations of the substances being mined (gold, copper, zinc, etc.), but the purity achieved can be rather low - in the order of 20 to 40%.

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[16] An ore is a rock containing a high concentration of useful minerals or metals which can be recovered at a profit. An ore also contains materials without value called gangue. There are some 3,000 types of ores on our planet and these include, for example, chalcopyrite ($CuFeS_2$) and malachite ($CuCO_2.CU(OH)_2$) which contain copper as a useful metal.

Melting and refining are used to obtain pure metal or to prepare alloys; these processes are partly carried out on site. In the case of gold, in Quebec, the product that leaves the mine for metallurgical processing is pure to about 96%. This section will not deal with the environmental

effects of foundries, steel plants and aluminum smelters (for example, see the grid showing the impacts of aluminum production).

Canadian socio-economic overview

In Canada in 1995 there were 88 metal production operations, 127 operations producing non-metal substances and 318 sites identified as quarries or facilities for the production of building materials. Mining industry revenues came mostly from metal mines (68%), followed by non-metal mines (17%) and quarries (15%). Most of Canadian mining production (80%) is exported; this industry ranks second in export revenues (behind logging). Metal and non-metal products account for 14.6% of total Canadian exports. In 1994, exports from the mining industry contributed $11.7 billion to the trade surplus. In terms of jobs, there were 35,000 workers in metal mines, 10,800 in non-metal mines and close to 6,000 in quarries and operations producing building materials.

Canada is the world's leading exporter of minerals. It ranks first in the production of zinc (28% of world production) and potash (36%). It is second in the production of nickel (17%), cadmium (12%), asbestos (19%) and elemental sulphur (22%). The Canadian mining industry is most active in Ontario (30%), followed by British-Colombia (18%) and Quebec (16%).

Quebec socio-economic overview

Close to 30 mineral substances are mined in Quebec. In 1996, the main metals mined were iron ore (15 million t), copper (127,000 t), niobium (2,362 t), cadmium (333 t) and zinc (200 t). The main non-metals mined were silica (527,000 t), asbestos (519,000 t) and sulphur (156,000 t). Metallic substances produced in Quebec accounted for 24% of total mining production in Canada and for 19% of metals. The percentage of mining in the Quebec Gross Domestic Product has been stable for several years at about 1%.

Gold mine operations

Background on gold mining

Gold is a metal that is non-corrosive, very ductile, malleable and conductive. It is sought for its many industrial uses such as in electronics, high technology and dentistry. Its greatest use is for jewelry-making (84% of demand).

However, world demand for gold, which greatly influences decisions on whether or not to open new mines, is driven by the monetary policies of central banks and financial institutions in general. These policies have an effect on the price of gold which, for example, declined from $417 an ounce in February 1996 to $212 in January 1998. With such conditions, opening a new mine can be delayed; if the price of gold is too low, mining operations could face a deficit.

In 1996, the world production of pure gold was 2,328 metric tonnes, the majority of which came from South Africa (490 t) and the United States (300 t). Canada produced 160 tonnes of gold in

1996, of which 42 tonnes came from Quebec where this precious metal is mined in some 20 underground mines, all in the areas of Abitibi and Chibougamau.

Gold ore is usually trapped in a quartz or sulphide gangue. In Quebec, 85% of gold comes from gold-bearing quartz mines. This is worth mentioning since contrary to sulphide ore, quartz ore produces minimal acid mine drainage (see below). To remove the metal from its gangue, gold ore is processed using various methods based on the use of cyanide. The gold is dissolved in a sodium or calcium cyanide solution and is then recovered (by precipitation) using a zinc powder (old method) or by electrolysis with activated charcoal (more recent method).

Pollution produced by heavy vehicles

The movement of heavy trucks in the communities near a mine can cause in a serious pollution problem. With today's ore mining and purification techniques, it is much more cost-effective to process the ore in a plant located outside the perimeter of the mine itself. This can involve movement of 500 to 1,000 tonnes of ore a day, the equivalent of 20 to 40 trailer-loads. This activity increases the risk of accidents, causes damages to roads and leads to greater air and noise pollution.

Water pollution

The mining industry in general uses a considerable amount of water for ore processing. In the case of gold mining, in Quebec, each year over one million tonnes of water is used, or approximately 2.3 m^3 per tonne of crude ore processed. The general pollutants that can be found in mining effluents include suspended particulate matter (SPM) and various metals attached to the gangue. Emphasis should be placed, however, on two types of pollution that are especially harmful to the environment: acid mine drainage and the use of cyanides.

Acid mine drainage (AMD)

Acid mine run-off water produced during mining operations is the mining industry's greatest long term environmental problem. This acid mine water is produced because most metals are trapped in sulphide ores, such as iron pyrite. The exposure of sulphide ores to air and humidity results in oxidization, which releases sulphuric acid. This acid production can continue for hundreds of years and becomes almost impossible to stop. The speed of the process increases under the effect of naturally occurring bacteria which catalyzes the reaction by oxidizing the iron sulphide and elemental sulphur. Microbiological oxidization is 500,000 to a million times faster than open-air oxidization under similar environmental conditions. These bacteria belong to the type *Thiobacillus* sp, which is harmless to mammals.

Acidity of mining effluents or leaching run-offs from tailing storage areas (referred to below) is a threat to aquatic wildlife, but does not pose any real problem for public health. Acid mine drainage can increase the toxic effect of cyanide, especially by promoting the formation of hydrocyanic acid (HCN), which is very toxic (see below). Furthermore, high acidity in water causes the release of various metals (aluminum, arsenic, cadmium, copper, iron, lead, nickel and zinc) found in the gangue and also in the parent rock on which the water flows. It should be noted that AMD is especially a problem in the case of copper, zinc or polymetal mines. In gold mining, run-off water is alkaline and therefore sulphides are not oxidized into sulphates.

AMD can be controlled in several ways, including by overwashing non-oxidized mine tailings. With this approach, the tailings are submerged in water, which prevents the oxygen from reaching the sulphide ore and initiating chemical oxidization.

Cyanides

Gold processing involves, first of all, the use of a sodium cyanide solution in an alkaline medium. This dissolves the gold, which is then separated from the tailings by absorption of the cyanide complexes. The gold is then submerged in a hot sodium hydroxide solution to allow stripping (and reuse) of the cyanide. The result is a concentrated solution of the precious metal. Although most of the cyanide is reused, the run-off water from the product that was used to filter the cyanide-gold complex can contain low residual quantities of this toxic substance.

It should be noted here that cyanides contain various types of inorganic and organic compounds in the CN group, which is formed by a triple link between a carbon atom and a nitrogen atom. Based on their physical and chemical properties, cyanides can be classified as a free, simple, complex or organic. In an aqueous environment, free cyanide corresponds to the total of free anions (CN), in equilibrium with a molecular type, e.g. hydrocyanic acid or hydrogen cyanide (HCN), the pH being the determining factor in this equilibrium. Simple cyanides are compounds where the CN radical is associated with metals or non-metals; in water, these compounds break down easily to form the CN anion. Complex organic cyanides are formed mostly with iron (ferrocyanides), copper (cuprocyanides) and zinc; these complexes are very persistent in the environment. The formation of thiocyanates should also be mentioned here. These are the product of the amalgamation of cyanides and sulphide compounds found in various ores or generated by AMD.

The presence of cyanides in surface water is usually the result of human activity, especially gold mining. In certain extreme cases, cyanide concentrations of 26 mg/L have been identified in mining effluents; according to directive 019 of the Quebec Department of the Environment, the CN level should not exceed 0.1mg/L.

Cyanides break down under the sun's rays, especially UV rays. The risk of water contamination is especially high in spring because during winter, ice prevents the ultraviolet rays from reaching the cyanides in free-floating water or in water that has accumulated in a pond mostly covered with ice. Therefore, no wastewater should be released between November and April. If water is released too early in the spring or if there is a leak in the restraining dikes, water laden with

cyanides can be spilled into the environment. The breakdown of cyanides by the sun's rays is a process that is widely used to help eliminate cyanides in ponds spread out over large areas.

There is a close link between the toxicity of cyanides and their types. Free cyanide is the most toxic form. Simple cyanides, however, break down quickly into free cyanide in water. Hydrocyanic acid (HCN), the form generally found at the pH levels in surface freshwater, is also very toxic. HCN penetrates quickly into the organism and starts acting by adhering to the ferric iron group (Fe^{+3}) which plays an active role in several enzyme systems. In humans, over 40 enzyme systems can be deactivated by cyanide, the most important being the cytochrome oxidase complex, which is at the top of the chain of respiratory carriers for mitochondria. With the inhibition of this system, the generation of ATP stops, and this produces the same pathological effect as a lack of oxygen in the blood. Oxygen can reach the cells, but they are unable to use it. Cyanide acts quickly and can be fatal within several minutes. The typical symptoms are weakness, headaches and tachycardia. Poisoning by cyanide can be treated when a kit containing various antidotes is available.

It is highly improbable that humans could be poisoned because of the presence of cyanide in mine wastewater. However, since this compound is so toxic, its presence in water is always a concern because the LC_{50} (96 hours) varies between 0.03 and 0.15 mg/L in most freshwater fish. This makes it a more powerful toxin than mercury and all of the heavy metals. In the spring, there have been many reports of Canada geese dying after having stopped in ponds where the water had a high cyanide content.

Mine tailings

Mining losses can include overburden which is made up of the layers covering a deposit. However, such losses are produced in limited quantity and do not have a real harmful effect on the environment, except when they produce dust that can be raised by the wind, or when rainwater can cause erosion. The most harmful wastes are the mine tailings themselves, which fall into two categories: waste rock and mineral processing waste. Waste rock is rock that contains insufficient quantities of metal (or non-metal) to be commercially mined. This material is produced when digging the access ramps, tunnels and underground shafts to reach the gold-bearing areas of the mine. Ore processing waste includes mostly the gangue that is removed through the various concentration operations.

Mine tailings can be stored in piles, depending on their particle-size. Most typical of these in Quebec are the piles of asbestos tailings in the Thetford Mines area. In Quebec, there are close to 150 mine tailing storage areas covering approximately 12,000 hectares. Gold mining accounts for one third of these sites. These tailing storage areas also provide excellent sites for the development of acid mine drainage.

Various methods can be used to restore mine tailing storage sites to an environmentally acceptable condition. Water run-off can be contained and controlled, and contact with the air can be prevented. These are necessary steps to prevent AMD. Abandoned tailing sites can be covered with impervious soil on which vegetation can be planted.

Sector: Mining Activity: Underground Gold Mining

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- rupture of retaining dikes	water pollution from cyanides and heavy metals	mine and receiving watercourse, if any	- monitoring	
	-collapse and flooding of tunnels			- solidification of tunnels	
Gaseous or air emissions	suspended matter	- deposit on vegetation, appearance	- site and perimeter	- dust control liquid on access roads - vegetation cover on abandoned tailings	150 $\mu g/m^3$ (24 hrs) Q-2, Reg. Qual. Atmosph.
Liquid emissions or discharge into water	- cyanides	- high toxicity for aquatic organisms: (CL_{50}: 0.03 to 15 mg/L)	-receiving water courses and water bodies	- retention pond (to facilitate degradation)	- 0.2 mg/L (Drinking Water Reg., DEW) - 20 $\mu g/kg/j$ (EPA)
	- heavy metals (Al, Cd, Cu, Zn, Pb, Fe, Ni, etc.)	- varying toxicity for aquatic organisms	- receiving watercourses and water bodies	- treatment pond	- 5 μ g/L (Cd), 0.5 mg/L (Pb) (Drinking Water Reg. DEW) Al <0.1 mg/L (to prevent Alzheimer's disease)
	- pH reduction (sulphuric acid)	- toxicity for several aquatic organisms	- receiving watercourses and water bodies	- prevent sulphide ore oxidation	- pH 6.5 to 9.5 (Mining Guidelines, DEW)
Solid emissions or discharge into the soil	- overburden	- appearance (possibility of dust in atmosphere)	- site and perimeter	- adequate storage	- Mining Act and Mining Guidelines (DEW)
	- waste rock and tailings	- appearance (possibility of cyanide & heavy metals in water)	- site perimeter and vicinity	- adequate storage, prevent sulphide ore oxidation	- idem
Disamenities	- dust	- healthy conditions, appearance	- site, perimeter and vicinity	- covering, dust control	
	- noise (mobile and fixed sources)	- healthy conditions	- site, perimeter and vicinity	- buffer zone	- L_{eq} 45 dB(A) 8 hrs nighttime and 50 dB daytime
Indirect impacts or other exposure					

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Technological disaster	- see "cyanides" and "heavy metals"	- workers	- occasional	- morbidity/mortality reports, CSST	
	- injuries, deaths				
Gaseous or air emissions	- various respiratory problems	- workers, vicinity	- rare	- complaints, levels of atmospheric particulate matter	
Liquid emissions or discharge into water	- weakness, headaches, tachycardia, death	- vicinity, people drinking contaminated water	- very rare	- total cyanide levels in mining effluents and in receiving watercourses	- Gossels and Bricker (1994); OECD (1994)
	- various toxic effects	- vicinity, people drinking contaminated water	- very rare	- heavy metal levels in mining effluents and watercourses	- Gossels and Bricker (1994)
	- none	- N.A.	- N.A.	- N.A.	
Solid emissions or discharge into the soil	- none	- N.A.	- N.A.	- N.A.	
	- see cyanides and heavy metals in water				
Disamenities	- hygiene, infections	- workers, vicinity	- rare to occasional	- complaints	
Indirect impacts or other exposure					

References

Mining Association of Canada and Industry Canada (1995). What Metals and Minerals Mean to Canadians. Mining Association of Canada, Department of Industry (Government of Canada), 35 p.

AMQ (1996) Bilan environnemental 1993-1995. Association minière du Québec, 23 p.

Anonymous (1991) Normes d'effluents basées sur la technologie pour les secteurs des mines et de la métallurgie. Produced by Laboratoire Écosag (LMB Group) for the Quebec Department of the Environment, 48 p. (+ appendices)

Canada (1996) State of the Environment in Canada. Government of Canada, 820 p. (Chapter 11)

Chevalier, P. (1995) Gestion de l'environnement en milieux urbain et industriel. Presses de l'Université du Québec, 577 p.

Chevalier, P. (1996) Technologies d'assainissement et prévention de la pollution. Presses de l'Université du Québec, 440 p.

Environment Canada (1987) Mine and Mill Waste Water Treatment. Department of the Environment, Government of Canada, 92 p.

Gauthier, B. (1993) Un modèle de développement durable appliqué aux industries minières du Québec, Department of the Environment and Wildlife, Government of Quebec (unpublished), 94 p.

Gossels, T.A., and J. D. Bricker (1994) Principles of Clinical Toxicology. Raven Press, 3rd Edition, New York, 447 p.

Grenier, M., and L. Blais-Leroux (1997) L'industrie minérale au Québec (1996). Department of Natural Resources, Government of Quebec, 119 p.

Department of the Environment and Wildlife (1992) État de l'environnement au Québec. Government of Quebec, Les éditions Guérin, 560 p.

OECD (1994) Environmental Dagradation from Mining and Mineral Processing in Developing Countries: Corporate Responses and National Policies. Organization for Economic Cooperation and Development, Paris, 103 p.

Vachon, A. (1990) Guide des règles de l'art dans la gestion optimale des rejets miniers. Le groupe Roche (Quebec), 71 p.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2
Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 7 of 11

Agriculture

The Canadian outlook

Despite its size, only 11% of Canada's total area has agricultural potential, and less than 5% of this land is really suitable for agriculture. Nevertheless, agriculture and the agri-food business play an important role in the country's economy with a contribution of $23.8 billion to Canada's GDP in 1993. Furthermore, Canada is a net exporter of agricultural products, with the value of these exports totaling $14 billion in 1994. The main producing sectors in the Canadian agricultural industry are meat (beef, porc, veal and lamb), grain, and oilseeds (wheat, durum wheat, barley, flax, rapeseed, soya, and corn).

Canadian agriculture has changed considerably over the past several decades in response to various forces. For example, the number of farm operations has decreased steadily, from over 700,000 in 1941 to less than 300,000 in 1991. At the same time, there has been a steady increase in the size of the operations (from about 50 hectares in 1941 to 250 hectares in 1991). This has resulted in important changes that have launched the industrialization of agriculture, as typified by soilless hog raising facilities housing several thousand animals.

Agriculture in Quebec

Agriculture in Quebec underwent profound changes after the Second World War, when regional specialization occurred in Canada (grain production in the west, and dairy and vegetable production in the east). Furthermore, the agricultural crisis in the 50s brought about a gradual disappearance of traditional agriculture. This process, ongoing for four decades, continues today. The transition toward industrial agriculture, evidenced by regional specialization, mechanization and the increasing use of fertilizers and pesticides, was also accompanied by a significant decrease in the number of farms and by more intensive use of better quality land, while land with serious limitations was abandoned. The final stage of this phase, which began in the mid-80s, is the development of environmental awareness in the agricultural community.

In Quebec, there are 6.4 million hectares of land suitable for farming, but only 2.3 million hectares have good agricultural potential (land classed 1 to 3). This type of land, about 1 million hectares, is mostly concentrated in the St. Lawrence lowlands. This is the region where the environment is most threatened by agricultural practices.

Animal production dominates agriculture in Quebec, involving 70% of the 46,000 producers in Quebec. Thirty percent of farmers specialize in vegetable production. Dairy farming is the most important agricultural activity in Quebec, supporting 33% of all producers. Next in importance are beef and veal calf production, with 21%, grain and protein crop production (soya, rapeseed) with 9.7%, followed by fruits and vegetables (7.5%). Hog farming (6.8%)

ranks just ahead of maple syrup production (6.4%). Other types of agricultural production (horse breeding, poultry, forage crops, etc.) each account for less than 5% of agricultural activity. In 1996, revenues from all animal and vegetable productions totaled $4.6 billion, with vegetable production accounting for 20% and animal production accounting for 66%. Government payments and miscellaneous productions not classified elsewhere account for the remaining percentage.

A different picture is revealed when revenues are considered. Indeed, dairy production dominates the agricultural sector (35% of revenues or $1.4 billion), followed by hog farming with 18% of revenues ($730 million). Poultry farming (11% of revenues or $470 million) and beef production (9% or $360 million) are ranked respectively 3rd and 4th, followed by vegetable production excluding potatoes (6% or $228 million), and by wheat and grain production (6% or $221 million).

In 1995, direct agricultural activity (excluding fishing and food bio-processing) accounted for 1.1% of the Gross Domestic Product in Quebec, with a share of the GDP totaling $1.8 billion. Downstream from agricultural production, food and beverage processing generated a sectorial GDP of $3 billion. Employment in the agricultural sector supports 2.1% of the labour force in Quebec, with some 67,600 workers directly involved in agriculture. When food bio-processing is included, another 47,000 jobs can be added to this sector.

In conclusion, the political importance of agriculture in rural areas should also be mentioned. The agricultural community is represented by various groups, the most important being the Union des producteurs agricoles (UPA). This organization is based on a union model and is dedicated to the defense and promotion of the professional, economic and social interests of its members. It has a membership of 50,000 producers and it is the umbrella organization for 16 regional federations and 21 specialized federations. Each federation consolidates all grassroots and specialized unions in its area. The UPA is also a powerful mechanism for lobbying governments, frequently making representations on behalf of its members.

References

Canada (1996) State of the Environment in Canada. Government of Canada, 820 p.

Canadian Federation of Agriculture (1994) Agriculture in Canada. Canadian Federation of Agriculture, Ottawa, 32 p.

Chevalier, P. (1993) Gestion des ressources renouvelables : secteurs agricole et forestier. Presses de l'Université du Québec, 558 p.

Dionne, S., S. Picard, and N. Lafrance (1997) Profil sectoriel de l'industrie biioalimentaire au Québec (1996 Edition). Department of Agriculture, Fisheries and Food, Government of Quebec, 83 p.

Guillot, P., N. Morin, and N. Lafrance (1997) Bottin statistique de l'alimentation (1996 Edition). Department of Agriculture, Fisheries and Food, Government of Quebec, 59 p.

Quebec Department of Agriculture, Fisheries and Food (1995) Chiffres clés du Québec bioalimentaire. Pamphlet produced by the Quebec Department of Agriculture, Fisheries and Food.

Statistics Canada. 1996.

Hog farming and health

Socio-economic overview

Hog farming has been condemned as one of the most polluting agricultural activities. With the rise of this industry over the last 20 years, environmental problems have increased to the point where confrontations have occurred in several rural municipalities.

Hog farming experienced tremendous growth at the end of the 70s, as is evident from the figures below. In Quebec in 1961, there were a little over one million hogs (1.114 M), and this number remained relatively stable for 17 years[17]. However, starting in 1977, the number of hogs rose from 1.076 M to 1.792 M in 1978, and 2.760 M in 1979. The number of animals totaled over 3 million in 1980 and peaked in 1983 at 3.104 M. This vigorous growth was the result of favorable economic conditions and strong financial incentives provided by the government for the construction of hog raising facilities.

With the recession of the early 80s and the stabilization of demand, the number of hogs remained stable until 1990 (3.055 M animals). New growth occurred starting in 1991, but it was much weaker than the growth of the 1977-1980 period. In 1995, in Quebec there were close to 3.4 million hogs, the majority of which (3 million) were feeder pigs slaughtered a few months after birth. In 1995, 5 million hogs were produced, 2 million of which were slated for export.

Over the years, several regions in Quebec demonstrated that they were particularly well suited for hog raising. Quebec production is dominated by growers in the valley of the Richelieu River (including the St. Hyacinthe region), with a production of 25%, followed by the Beauce region (20%), the Quebec region, excluding the Beauce region (17%), and the Eastern Townships (16%).

The hog industry contributes considerably to the trade balance in Quebec in the area of agri-food. In 1995, the hog industry generated $730 million, or 18.2% of total agricultural revenues in Quebec. The number of jobs directly related to this industry is estimated at close to 6,000, with the number of indirect jobs totaling 25,800. A considerable portion of production is exported. Pork was the main agricultural export from Quebec in 1996, with a value of $455 million, representing 33% of agri-food exports from the province. Japan, the United States and South-East Asia are the main export markets. However, continued growth of hog meat exports is not assured. For example, the Asian financial crisis of 1997 and 1998 has resulted in decisions by the countries of that region to reduce their imports of hog meat.

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[17] These figures represent the number of live animals at a given date, ordinarily July 1. This number is lower than the actual number of animals slaughtered in one year, because the animals are slaughtered less than one year after birth.

Type of operations

Large scale "soilless" hog raising operations are classified as industrial. This is because they could very easily be located in an industrial park if it were not for the necessity of spreading the pig slurry[18], or if this slurry could be easily processed to benefit from its potential as fertilizer, thus eliminating it more readily. Pigs are given industrially-produced feeds, and in this respect as well, a mega hog raising operation need not be located in a rural environment, if it were not for the requirement of spreading the slurry. Each year, hogs in Quebec generate a little over 7 million cubic metres of droppings. However, hog farms operate with what is called a liquid management system for droppings, in which the manure is mixed with urine and where no litter such as sawdust, straw or peat is added. With such a management system, the total volume of pig slurry that must be processed annually is approximately nine million cubic metres.

Risks to the public

Pollution caused by animal droppings

Animal droppings managed in liquid form represent a potentially greater burden for the environment. Pig slurry contains high concentrations of microorganisms, some of which can cause diseases in humans. This slurry is laden with minerals (nitrogen, phosphorus, potassium, etc.) and also with various organic materials. Nitrogen and phosphorus compounds are nutrients that foster growth of algae and other marine vegetation. As for the organic matter that finds its way into the water system, it uses up a considerable part of the oxygen, generating an overload of substances that cause the proliferation of various organisms. Liquid management of animal droppings is the method with the most negative environmental impacts; in addition, it is most likely to produce very strong odours.

Water pollution

Four watersheds are especially affected by pollution by agricultural operations where manure or slurry is produced in excessive quantities. These are the watersheds of the Yamaska, Chaudière, Etchemin and Assomption rivers. There is a significant concentration of hog farms in those regions. Overall in Quebec, and especially in these four catchment areas, the quantities of nitrogen and phosphorus from animal droppings far exceed the capacity of the soil to absorb these substances. Indeed, for all of Quebec, these two sources, manure and slurry, cover crop requirements in nitrogen and phosphorus respectively at a level of 133% and 167%. In the case of nitrogen requirements, percentage coverage in the Yamaska watershed is 144%, in the Chaudière watershed, 267%, in the Etchemin watershed, 252%, and in the Assomption watershed, 176%. As for phosphorus, the requirements are covered in these watersheds respectively at 285%, 220%, 265% and 280%. In 1996, according to figures provided by the Plant Protection Council of Quebec (CPVQ), the surface areas required to spread the phosphorus and nitrogen from manure in these four watersheds were 2 to 5 times greater than the actual land available.

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[18] Slurry includes all waste with a water content greater than 85 to 90% and is in liquid form. Otherwise, animal droppings are called manure. Manure effluent, not to be confused with slurry, is the liquid flowing from manure.

The Yamaska River is one of the most polluted rivers in Quebec. The river is in this condition because of industrialization, municipal sewage and agriculture. Between 1975 and 1988, nitrate levels in the river's water increased by 100%. As for hog farming, there are over 1,000 slurry pits in this area, demonstrating the extent of these operations. There are currently about 1 million pigs in this catchment area.

Water quality in the Chaudière River has declined considerably since 1960. Already in 1985, this catchment area had to support a number of animals per hectare exceeding by the acceptable limits by 300%. Hundreds of operations have surplus animal droppings, 90% of which is pig slurry. An additional 50,000 hectares would be required to spread the pig slurry and cattle manure. It is estimated that there are 650,000 pigs in this catchment area.

The Etchemin River, which has a low waterflow, is highly polluted from one end to the other by bacteria, organic matter or nutrients. The pig population in this catchment area is estimated at 300,000.

Water quality in the Assomption River is generally good in its upstream area, but it declines rapidly downstream from some tributaries such as the Saint-Esprit and Achigan rivers that flow through agricultural land. Hog farming, with close to 250,000 heads, has been identified as an important source of pollution.

Water pollution is usually caused by leakage from storage pits and by improper spreading (over-fertilization), which pollute surface and ground water. In the case of surface water, there can be a considerable lack of cleanliness if pollution exceeds certain levels. In this respect, the production of drinking water becomes more difficult. High levels of fresh organic matter not only produce trihalomethanes but also prevent water filtration systems from operating properly. In addition, in extreme cases, concentrations of nitrogen in the form of nitrates/nitrites in underground water can cause methemoglobinemia, especially if synthetic fertilizers are used in addition to slurry and manure.

Inorganic pollution

Total nitrogen levels in pig slurry can reach 3,500 mg/L, and phosphorus levels can reach 2,500 mg/L. This high nutrient content is caused in part by the fact that up to 70% of the nitrogen in animal feeds (meal) can be lost through improper handling or because of incomplete digestion.

Ammoniacal nitrogen (in the form of HN_3 or of NH_4^+) is an important component of manures and slurries. For example, a feeder pig excretes about 24 g of nitrogen per day (in inorganic or organic form) and 7 g of phosphorus, compared to 10 g and 2 g with humans[19]. A clearer picture of such a pollution load can be given by mentioning that the excretions from 6.9 million Quebecers produce daily 6,900 kg of nitrogen, whereas three million pigs generate 7,200 kg.

Organic pollution: microrganisms

Slurry contains high levels of microorganisms, usually between 10 and 100 million per ml. The main hazards to human health from pathogenic microorganisms in pig slurry are bacterial enteritis caused by *Salmonella* sp, *Campylobacter* sp and *Yersinia enterolitica*. Other bacteria, such as *Escherichia coli*, parasites such as *Cryptosporidium* sp, and viruses can also occur. There is evidence also that bacteria of the type *Listeria* occur quite frequently in pig excrement. However, current data allows only a partial assessment of the magnitude of this problem. In the case of diseases whose reporting is mandatory, in Quebec in 1995 there were several cases of infection caused by *Campylobacter*, of salmonellosis, and of gastroenteritis caused by *Yersinia enterolitica*. However, it is believed that the number of cases identified is much lower than the real number of occurrences, and furthermore, the origin of the infection is unknown most of the time.

As for outbreaks of water-borne infectious diseases, data for the Chaudière-Apalache region, one of the most vulnerable to agricultural pollution, indicates that between 1989 and 1995, five outbreaks of gastroenteritis affecting 247 persons were possibly related to agricultural activities. However, these cases were not specifically linked to hog production. The fact that the origin of the contamination remains unknown in over 40% of the epidemics reported in Quebec increases the probability that other outbreaks may be caused by non-point source pollution from agricultural practices.

Organic matter

Organic matter found in surface water processed by filtration plants can be natural in origin or can result from human activities in general. It is recognized however that in rural or semi-rural regions, animal breeding constitutes an important source of water pollution through organic matter.

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[19] This is a mathematical average, and the values can vary for each class of feed pig (20-42 kg, 42-70 kg, etc.)

In Quebec, there are many hog farms in catchment areas that supply water to relatively large municipalities. Such rivers include the Saint-François, the Yamaska, the Richelieu and the Assomption. At 40,000 mg/L, the biochemical oxygen demand of slurry is considerable; in fact, it is 250 times greater than ordinary urban wastewater. Furthermore, it can be reasonably assumed that chlorination byproducts are formed in water treatment plants. These represent a risk for public health.

Formation of chlorination byproducts

When drinking water is disinfected with chlorine, water-borne infectious diseases are reduced considerably. However, when water containing high levels of organic matter is treated with chlorine, toxic byproducts are produced, such as trihalomethanes (THM), halogenated acetic acids (HAA), halogenated acetonitriles (HAN), picrines, aldehydes, and phenols. THMs, especially chloroform, are the main substances that have been studied, and it was long believed that these were the most important in terms of health risks. We know today that this is not always the case and that, for instance, halogenated furanone (MX), even in low concentrations (in the order of 20 or 30 nanograms per litre), accounts for 40 to 60% of the mutagenicity of drinking water. Although it is difficult to establish any causal relationship, a significant link is suspected between the absorption of chlorinated water over many years and cancer of the bladder.

The best way to prevent water pollution caused by slurry is to ensure that it does not leak, and to enforce strict rules for spreading, to prevent run-off of slurry into watercourses. However, even when best practices are applied, they cannot account for over-fertilizationwhich causes over-saturation of the soil with nutrients. In this context, the implementation on farms of an environmental plan for fertilization, as required by the*Regulations Concerning the Reduction of Agricultural Pollution* (1997), should provide a solution to some of the problems associated with over-fertilization.

Odours

There has been a considerable increase in odors from animal production operations over the last 30 years in Quebec, mostly because of the transition from solid to liquid management of manure, especially in hog farming. The result has been a 5.2-fold increase, between 1961 and 1995, in odors from buildings and storage facilities for pig slurry, with a 8.2-fold increase when spreading operations are conducted.

Odours linked to animal production can be released by over 75 different compounds. Droppings are clearly the main source of smelly compounds, which result from bacterial activity in the intestines and from fermentation at a later stage, usually under anaerobic conditions. Theoretically, this type of fermentation produces methane and carbon dioxide (two greenhouse gases), but very often there is only partial methanization, producing smelly compounds such as volatile fatty acids and sulphur compounds (H_2S, CH_3SH – [methylmercaptan], CH_3SCH_3 [dimethylsulphide]).

Slurry releases few odors when it is stored, but as soon as it is stirred, volatile compounds are released. Therefore, the strongest odors are produced when the slurry is taken from the tank, transported and spread.

Air pollution problems related to hog production originate in animal buildings (the animals themselves and the slurry that is stored), but spreading is also an important source of odour nuisances. Spreaders that avoid dispersal and spraying of the slurry are recommended; with some systems, it is possible to spread the slurry very close to the ground, and even to mix it with the soil. As for the odours released by the animal buildings, it is suggested that the animals' diet be modified, that the air undergo biological filtration before being released, and that deodorizers be used. New breeding techniques such as the use of biocontrolled litter are also suggested. In this system, the animals are raised on a 70 cm thick bed of litter, in which microorganisms are activated to produce composting in the litter itself. This results in less odour production, and destroys pathogenic microorganisms.

Risks for workers

Constant exposure to the air inside a hog house can lead to several acute and chronic respiratory problems for people who work in this environment. Workers often suffer from eye, nose and throat irritations, and from chronic bronchitis and asthma. It is estimated in fact that the air in hog

houses is 1,200 times more laden with microorganisms than ambient air. The bacterial content of air in hog houses has been well documented. It contains large amounts (10^5 to 10^7 ufc per cubic metre of air) of Gram-positive bacteria such as *Staphylococcus* sp., *Micrococcus* sp. and *Bacillus* sp. However, respiratory problems seem more closely connected with Gram-negative bacteria such as *Acinetobacter calcoaceticus, Flavobacterium* sp., *Pseudomonas* sp. and *Serratia marcescens*, mostly because of the effect of their endotoxin. The incidence of chronic bronchitis is very high among pig farm workers - from 15 to 40% according to studies. Occupational asthma also affects many workers and often forces people to seek work elsewhere. These respiratory problems are mostly linked with high levels of dust, gas and microorganisms in the air of the buildings. The presence of mold in the air is also responsible for health problems such as organic dust toxic syndrome, and, to a lesser extent, for extrinsic allergic alveolitis, or farmers' lungs, whose main causal agent is *Saccharospora rectivirgula* (formerly *Micropolispora faeni*).

Finally, hog farm workers can suffer from various zoonotic diseases. Erysepeloid (*Erysipelothrix rhusiopathiae*), a non-malignant skin infection caused by a streptococcus, often affects hog farm workers. It produces a painful sore that swells around the edges. These workers are also exposed to *Yersinia enterolitica,* which can cause intestinal infections and which may be linked with higher rates of appendicitis. Hog farm workers are also exposed to intestinal diseases caused by *Salmonella* sp and *Campylobacter* sp. In rarer cases, *Streptococcus suis* can cause severe systemic illness in the form of meningitis, pneumonia, endocarditis or arthritis. The risk of contracting leptospirosis, tuberculosis or brucellosis is rather low because these animal diseases are generally well controlled.

Hog producers and their employees are also exposed to poisoning by manure gases, which can occur mostly when work is being done in temporary manure storage areas. Most often, the agent responsible is hydrogen sulphide (H_2S). Half of the severe cases of manure gas poisonings are fatal.

Social and human impacts

The development of large hog raising operations and the large scale spreading of pig slurry are currently a problem in Quebec because of the strong odors that affect the quality of life of people living in those areas. Supplemental analyses were conducted recently on data provided by the 1992-1993 Quebec Social and Health Survey, to study mental distress related to high densities of hog raising operations (Pampalon 1997). The results reveal that in spring and summer, as compared to autumn and winter, there is a significant increase in high levels of mental distress (from 20.8% to 34.3%) in municipalities with large numbers of hog raising operations (20,000 pigs or more). Slurry spreading activities might be responsible for such a reaction. However, the authors point out that based on these results, no causal relationship can be established between hog raising activities and mental distress. They do consider that such a link can be seriously hypothesized, and that further analysis of the data should be conducted or, preferably, that a specific study should be undertaken on this issue.

Sector: Agriculture
Activity: Large Scale Hog Farming

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- fire, explosion	- deposits, fumes	- site and perimeter	- covering, capture	- ?
	- leakage from slurry pit	destruction - soil and water pollution	- site, perimeter, vicinity	- sealing, repairs	- monitoring facility witnesses
Gaseous or air emissions	- methane, N_2O	- greenhouse effect	- world-wide	- capture	- none
	- bacteria and endotoxins *Acinetobacter, Flavobacterium, Pseudomonas Serratia*	- pollution	- site	- farming practices	- none
	- mold and actinomycetes	- contamination of air inside buildings	- site	- ventilation	- none
Liquid emissions or discharge into water	- nutrients (phosphorous)	- eutrophication, algae growth (see below)	- vicinity and community	- leakproof slurry pit, buffer zone observed when spreading	- $NO^2+NO^3=10$ ml/L (Q-2, Drinking Water Reg.); P: no standard
	- organic compounds	- BOD, oxigen deficiency in aquatic environment	- receiving waters	- same as above + biocontrolled litter	- 3 to 7 mg/L[20] (DEW criteria for raw water intake), 350 µg/L for THM(Q-2 Drinking Water Reg.[21]
	- suspended matter	- pollution, healthy conditions	- receiving waters	- same as above	- Q-2, same regulations as above
	- microorganisms: Salmonella Campylobacter Yersinia enterolit. Escherichia c. Cryptosporidium	- pollution, healthy conditions	- receiving waters	- same as above + use of biocontrolled litter	- fecal coli: 0 total coliform count: 10/100 mL

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[20] Applies mostly in the case of raw water that will be treated with chlorine, which can trigger the formation of cancerogenic trihalomethanes.

[21] Should be lowered to 100 µg/L in accordance with Health Canada's new Maximum Acceptable Concentration (MAC)

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
	- microalgae: *Microcystis*	- pollution, healthy conditions	- water receiving nutrients (N and P)	- activated charcoal and ozonation for drinking water	-microcystine: 1.5 µg/L (Health Canada)
Solid emissions or discharge into the soil					
Nuisances	odors	healthy conditions	vicinity and community	buffer zone; biofiltration of air inside the building; aeration of slurry; breeding practices	- municipal regulations - guidelines on odors in agricultural areas
Indirect impacts or other exposure	- inhalation of heavy sulphide gases in the temporary manure storage area	- N.A.	- N.A.	- avoid entering temporary manure storage area without adequate breathing equipment	- Regulation respecting entry into confined spaces, CSST? (Applicable to employees only)
	- downgrading, devaluation, and social conflict	- possible decrease in economic value	- vicinity, community, and region	- communications compensation	

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Technological disaster	- respiratory irritations, burns, deaths	- workers	- rare	- fire, morbidity, mortality reports	
	- unhealthy conditions	- vicinity	- rare to occasional		
Gaseous or air emissions	- climatic change - various respiratory problems - various zoonotic diseases - allergic alveolitis STEPO	- world-wide - workers - workers - workers	- frequent - frequent - occasional - rare to occasional - rare to occasional - frequent	- air emissions containing CH_4 and N_2O - presence of Gram-bacteria in the air inside hog confinement buildings - presence of mold spores and of actinomycetes	- Jacques (1992) Cormier *et al* (1990) Zejda *et al* (1994) Cormier *et al* (1990)
Liquid emissions or discharge into water	- methemo globinemia if N level is too high	- people (especially newborns) drinking	- very rare	- overt symptoms: respiratory problems, cyanosis ...	Levallois *et al* (1994) Laferrière (1996) Levallois (1997) Laferrière (1996) + Laferrière *et al* (1996) Anonymous (1995) + Internet references (see text)
	- unhealthy conditions + possible formation of cancerogenic trihalomethanes (THM): bladder, colon	polluted ground water	- frequent	- surface water BOD	
	- unhealthy conditions	- people using and drinking polluted water	- unknown	- trihalomethane levels in drinking water	
	- gastroenteritis, mucosal and skin infections	- people using polluted water	- frequent	- suspended matter levels in water	
	- hepatic toxicity, potential tumour-causing effect	- people using and drinking polluted water	- rare to occasional	- identification of indicator/pathogenic microorganisms	
		- people drinking polluted water	- unknown	- microalgae identification and determination of microcystine levels in water	

STRESSOR/ EXPOSURE	**Effect on health**	**Population at risk**	**Probability of occurrence**	**Environment/ biological indicator (monitoring)**	**Information/ references**
Solid emissions or discharge into the soil					
Nuisances	- stress, psychological problems, insomnia and nausea in extreme cases	- vicinity and community	- occasional to very frequent	- volatile fatty acids, sulphur compounds - complaints, perception studies	- Gingras (1996) - Gingras and Gosselin (1997) - DHSS (1996) - Pampalon and Legaré (1997)
Indirect impacts or other exposure	- poisoning, death	- workers	- occasional	- identification of heavy gases in temporary manure storage area - investigation report CSST, public health - assessment role, perception studies	CSE, CDSP, DHSS (1997)
	- quality of life stress	- vicinity, community, region	- very frequent		

References

Anonymous (1995) Microcystines et eau potable. BISE (Bulletin d'information en santé environnementale),6(6): p.7

Quebec Bureau of Statistics (1961 to 1990) Farming Statistics, number of pigs in Quebec, several issues between 1961 and 1990)

Buelna, G., P. Caouette, and S. Pigeon (1993) Désodorisation des lisiers : étude comparative des principales technologies existantes à l'aide des bilans et selon une approche intégrée. Sciences et techniques de l'eau, 26(4): 243-252.

Chevalier, P. (1993) Gestion des ressources renouvelables; secteurs agricole et forestier. Presses de l'Université du Québec, 558 p.

Quebec Environmental Health Committee, Quebec Public Health Directors' Council, Quebec Department of Health and Social Services, 1997. Hydrogen sulphide: Background paper for a definition of poisoning and significant exposure (discussion draft). 18 p. and appendices.

Cormier, Y., Tremblay, G., Mériaux, A., Brochu, G., and J. Lavoie, 1990. Airbone microbial contents in two types of swine confinement buildings in Quebec. Am. Ind. Hyg. Assoc. J., 52(7): 271-9

Plant Production Council of Quebec (1982) Report of the symposium on manure. Department of Agriculture, Fisheries and Food, Government of Quebec, 83 p.

Daigneault, R. (1997) Importantes étapes franchies dans la féforme du droit environnemental en matière agricole. In vivo (Bulletin of the Association of Biologists of Quebec), 17(4): 12-13.

Dionne, S.,S. Picard, N. Lafrance (1997) Profil sectoriel de l'industrie bioalimentaire au Québec. Department of Agriculture, Fisheries and Food, Government of Quebec, 83 p.

Gingras, B., and P. Gosselin (1997) Advice concerning the general policy proposal on the management of odors, noise and dust in agricultural operations, in relation to an Act to amend An Act to Preserve Agricultural Land and other legislation to protect farming. Quebec Environmental Health Committee, 19 p.

Gingras B. (1996) Les odeurs reliées aux activités agricoles. BISE (Bulletin d'information en santé environnementale), 7(5): 1-5

Gingras B. 1995. Tous les métiers de la terre. L'environnement de la ferme laitière familiale; l'exposition des personnes aux contaminants. 455 p.

Guillot, A., N. Morin, N. Lafrance (1997) Bottin statistique de l'alimentation. Department of Agriculture, Fisheries and Food, Government of Quebec, 59 p.

Jacques, A. P. (1992) Estimate of Canada's Greenhouse Gaz Emissions for 1990: Department of the Environment, Government of Canada, 80 p.

Laferrière, M. (1996) L'industrie porcine et les risques reliés à la santé humaine. Vecteur Environnement, 29(3): 27-31

Laferrière, M., J.-J. Minville, J. Lavoie and P. Payment (1996). L'industrie porcine et les risques reliés à la santé humaine. BISE (Bulletin d'information en santé environnementale, 7(2): 1-8

Laflamme, D. (1995) Qualité des eaux du bassin de la rivière Etchemin, 1979 à 1994. Quebec Department of the Environment, 43 p. + 8 appendices.

Lebeau, A., M. Morisset, J. Nolet (1996) Plan stratégique pour le développement de l'industrie porcine (1996-1998). Groupe de recherche en économie et politique agricoles (GREPA), Université Laval, 104 p.

Levallois, P. (1997) Qualité de l'eau potale et trihalométhanes. BISE (Bulletin d'information en santé environnementale, 8(6): 1-4

Levallois, P., and D. Phaneuf, (1994). La contamination de l'eau potable par les nitrates : analyse des risques à la santé. Revue canadienne de santé publique, 85(3): 192-6

Quebec Department of Agriculture, Fisheries and Food (1997) Conference on agriculture and agri-food in Quebec; reference document of the Department of Agriculture, Fisheries and Food, Government of Quebec, 73 p.

Martin, G. and P. Laffort (1991) Odeurs et désodorisation dans l'environnement. Tech & Doc Lavoisier, Paris, 452 p.

Department of the Environment and Wildlife (1996) Discussion paper on the capacity of farmlands in Quebec to support animal production. Working document, Department of the Environment and Wildlife, Government of Quebec, 32 p.

Department of Health and Social Services (1996) Les risques pour la santé publique d'un développement non contrôlé de la production porcine au Québec, Public Health Directorate, Department of Health and Social Services, Government of Quebec, 11 p.

Pampalon, R., and G. Légaré (1997) Détresse psychologique chez les résidents de municipalités productrices de porcs au Québec. Quebec Environmental Health Committee, 3 p.

Primeau, A., and Y. Grimard (1990) Rivière Yamaska, 1975-1988, volume I; description du bassin versant et qualité du milieu aquatique. Quebec Department of the Environment, 136 p. + 10 appendices.

Robert, L. (1991) La valeur fertilisante des déjections animales. Agriculture, 48(1): 22-29

Simoneau, M. (1991) Qualité des eaux du bassin de la rivière Chaudière 1976 à 1988. Quebec Department of the Environment, 207 p. + 9 appendices

Simoneau, M., and Y. Grimard (1989) Qualité des eaux du bassin de la rivière L'Assomption. Quebec Department of the Environment, 234 p.

Vallée, P., G. Parent, and M.-F. Blais (1991) La gestion des fumiers et l'environnement. Agriculture, 48(1): 15-21.

Zejda, J. E., Barber, E., Dosman, J.A., Olenchock, S.A., McDuffie, H.H., Rhodes, C., Hurst, T. (1994). Respiratory health status in swine producers related to endotoxin exposure in the presence of low dust levels. Jour. Occup. Med.: 36(1) 49-56

Internet Sources

National Cancer Center, New liver tumor promoters, the cyanobacterial cyclicpeptide toxins microcystins and nodularin:
http://www.ncc.go.jp/annrep92/acts/11can.html

Health Canada, Federal-provincial subcommittee on drinking water, 21st meeting (Ottawa, May 12-13, 1997):
http://www.hc-sc.gc.ca/datahpb/dataehd/English/bch/water_quality/subcommittee_21.html

The microcystins: http://luff.latrobe.edu.au/-botbml/mictox.html

Use of pesticides in apple growing operations

General information on pesticides

Agricultural industrialization has led to a greater use of synthetic pesticides of all kinds. With farms engaging in monoculture over extensive areas (e. g., wheat and corn), it became necessary to use pesticides to protect crops against insects and fungi, and also to control competing vegetation whose growth rate is usually greater than that of planted crops. The reason for such an extensive use of these compounds on a global scale is that agricultural products are threatened by some 8,000 fungus species, 10,000 insect species and 2,000 weed species.

Hundreds of active ingredients (starting material) can be used as herbicides, insecticides, fungicides and rodenticides. Many commercial formulas are mixtures of several pesticides. During the 19th century and the early 20th century, mostly inorganic substances were used, such as

copper sulphate, arsenic salts and mineral oils, whose toxicity could have a devastating effect both on the organisms targeted and on humans. DDT made its appearance following the Second World War. This was an organochlorine insecticide that was to become famous for its efficiency, as well as its toxicity and persistence in the environment.

The use of pesticides in industrialized nations generally increased steadily between 1945 and the early 90s. Over the past several years, there has been a leveling off and perhaps even a slight decrease in the agricultural use of these substances in a number of developed countries.

In Quebec, for example, active ingredients for pesticides sold in 1995 totaled slightly over 3 million kg, compared to 3.6 million kg in 1992. This represents a 15% decrease over 3 years. However, based on methodological principles, it cannot be claimed that there is a real downward trend; longer term monitoring is necessary to confirm such a trend. Herbicides are the most widely sold pesticide, with 56% of the market, followed by insecticides (16%) and fungicides (11.5%). In terms of chemical groups, carbonates (insecticides and fungicides) are the most widely sold (14% of the market), followed closely by popular herbicides such amides, acetamides and anilines (14%), triazines and triazoles (11.8%), and aryloxyacides (10.9%).

In Quebec, farm operators purchase a little over 78% of all pesticides sold, followed by the household sector (11%). Industrial, logging and landscaping applications represent each less than 5% of the market.

Apple production in Quebec

In Quebec, orchards cover about 8,900 hectares, representing slightly over 0.5% of the total crop surface area. This is greater than the land used for vegetable production (on an individual basis), but less than the land used for major crops, such as corn-grain, with 280,000 hectares, barley with 130,000 hectares, etc. Also, this land is shared by 1,800 producers, so that the average surface area is 5 hectares per producer. Very often, these are family orchards, operated from one generation to the next.

The greatest number of apple trees are semi-dwarf trees (1.3 million), followed by dwarf apple trees (982,000), and standard apple trees (604,000). McIntosh apples represent 76% of total production (56,000 tonnes in 1995), followed by Cortland apples (16.5%), Empire apples (5%), and Spartan apples (5%).

Pesticides and apple production

Apple growing is subject to numerous abiotic and biotic uncertainties. A prolonged thaw in winter followed by a sudden and severe freeze, or for that matter an extensive ice storm, can cause irreparable losses. Indeed, some small orchards have been almost completely wiped out because of such occurrences. In addition, some 15 insect species can attack apple trees. The apple fly is the most important among these. Approximately 10% of all insecticides used in Quebec are in fact targeted against this insect, which burrows into the fruit. Slightly over 7% of all insecticides are used to control plum curculio, which feeds on buds, fresh leaves and baby apples. Another insect harmful to apple trees, the European red mite, is also the subject of special attention, with 6.5% of all insecticides used in agriculture in Quebec targeted against it.

About 15 insecticides are recommended for orchards in Quebec, but the main products used are azinphos-methyl, dimethoate (organophosphorus products) and mineral oil-insecticide. Other organophosphorus products, such as diazinon and chlorpyrifos, are also used and have been detected in areas near certain orchards. On average, an orchard is treated three to four times a year with insecticides. These substances must not be spread during blossoming, to avoid harming insect pollinators.

Although insect pests greatly affect apple growing, approximately 70% of the pesticides that are spread are fungicides (compared to 30% insecticides). The main target of these fungicides is the scab, a fungus that primarily damages the fruit's appearance, leaving a type of scale on the skin. Long periods of rain, heat and humidity worsen the problem. The extent of the use of fungicides is evidenced by the fact that 7 to 16 treatments with these substances are applied annually in a typical orchard. The main active ingredients used are captan, myclobutanil (a triazole) and mancozeb (a dithiocarbamate).

In addition to the insecticide and fungicide treatments, 2 to 3 acaricide treatments are used. The total amount of pesticides used in apple production is considerable: compared to corn farming where 3 kg of active ingredients are used per hectare, apple farming requires 30 kg of active ingredients per hectare.

Studies carried out in Quebec on the presence of pesticide residues in apple growing areas and their effects on health have focused mainly on organophosphorus insecticides. Although the environmental persistence of these substances is much lower than organochlorines (they have a half-life of several days to several weeks, compared to years in the case of chlorinated substances), their acute toxicity is much higher, ensuring their efficiency. Organophosphorus compounds mostly affect the target insect by contact, because they inhibit cholinesterase, a neurotransmitter that regulates the level of acetylcholine when a neural impulse is produced.

The most widely used fungicide is mancozeb. As for captan and myclobutanil, their acute toxicity for mammals is generally lower than organophosphorus compounds. However, captan is considered a mutagenic and teratogenic agent; it is probably also a carcinogenic substance.

Residues following spreading

Studies conducted in Quebec reveal that high levels of pesticide residues are still present in the air 6 to 12 hours following spraying. In the case of organophosphorus compounds, concentrations exceeding 2 mg/m^3 have been observed. As for residues in the soil, the highest level detected was 1.7 mg/cm^2. The people most likely to be affected are apple growers and their families, and people living close to the orchards, i.e. under 30 metres from its perimeter. In this regard, it should be noted that the increase in outdoor activities in rural areas can lead to an increase in the number of people likely to be exposed to pesticide residues.

Potential toxicity

According to a 1996 study conducted in Quebec, the levels of organophosphorus compounds detected in the environment are insufficient to induce acute or chronic toxicity. The levels of alkyl phosphates (alkyl phosphates are a derivative used to measure the presence of organophosphorus compounds in the human body) identified in urine from people exposed to these substances correspond to body burdens 10 times lower than the NOAEL. It was concluded that the health hazard for directly exposed people and for the surrounding population was minimal. Acute poisoning resulting in neurological and digestive disorders can only occur when there is considerable exposure during handling of the active ingredients, or when the product is sprayed without taking adequate protection measures. The same statement cannot be made in the case of the other types of pesticides used in orchards.

Sector: Agriculture
Activity: Pesticide Spraying in Orchards

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	fire in pesticide storage facility	destruction, contamination	site and perimeter	covering, capture, and confinement, emergency plan	- none
Gaseous or air emissions	- organo-phosphorous insecticides[22]	- air pollution caused by pesticide drift, especi-ally with wind	- site and perimeter (up to 30 m from sprayed area	- avoid spraying during nesting and pollinization periods	- 0.2 mg/m^3 for skin contact (NIOSH)
	- fungicides[23]	- air pollution caused by pesticide drift	- site and perimeter	- avoid spraying during nesting and pollinization periods	- none
Liquid emissions or discharges into water	- organo-phosphorous insecticides	- disturbance of aquatic life. Toxicity can be very high (e.g., 3 μg/L for rainbow trout)	- surface water on site and at perimeter	- avoid spraying during rainy periods, buffer zone	- 0.07 μg/L for azinphos-methyl (DEW standards for raw water intake) - 0.03 m/kg/d (safe level for occupational exposure (EXTOXNET)
	- fungicides	- high toxicity: 56 μg/L for trout and salmon	- surface and ground water on the site and at the perimeter	- avoid spraying during rainy periods, buffer zone	- 15 μg/L for captan (DEW and Env. Canada criteria for raw water) 0.13 mg/kg/j
Solid emissions or discharge into the soil	- organo-phosphorous insecticides	- soil and water table pollution	- site and perimeter (up to 30 m from sprayed area)	- none	- none
	(see note 3) - fungicides (see note 4)	- soil and water table pollution	- site and perimeter	- none	- none
Nuisances	odours	- quality of life, stress	- vicinity	- buffer zone	- none
	noise (spraying operations)	-quality of life, stress	- vicinity	- less noisy sprayers	- none
Indirect impacts or other exposure	accidental spilling of pesticides (concentrated)	- contamination, destruction	- usually on the site itself	- capture, cleanup, decontamination - prevention	

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[22] Azinphos-methyl is the typical substance considered for reference purposes

[23] Captan is the typical substance considered

STRESSOR/ EXPOSURE	**Effect on health**	**Population at risk**	**Probability of occurrence**	**Environment/ biological indicator (monitoring)**	**Information/ references**
Technological disaster	injuries, poisoning, burns, deaths	workers, firefighters, vicinity	rare	morbidity/mortality reports	
Gaseous or air emissions	- cholinergic effects of varying intensity depending on extent of exposure	- workers, and producers and their families	- rare to occational	- alkylphosphate levels in urine: 5.3 mg/g - creatinine = NOAEL workers 2.2 mg/g creatinine = NOAEL children	Boudreault *et al* (1997) DEW (1997) Keifer (1997) EXTOXNET (Internet reference)
	- captan: dermatitis, allergies, potentially cancerogenic, teratogenic and mutagenic	- workers and producers and their families	- unknown	- ???	
Liquid emissions or discharges into water	- same as above	- people drinking contaminated surface water	- unknown	- same as above	Boudreault *et al* (1997) Giroux (1997) Environment Canada, Canadian Water Quality Guidelines (for captan) Keifer (1997)
	- same as above NOAEL: 12.5 mg/kg/d (rats) for captan	- people drinking contaminated surface water	- unknown	- ???	
Solid emissions or discharge into the soil	- same as above	- people drinking ground water	- unknown	- N.A.	DEW (1997)
	- same as above	- people drinking ground water	- unknown	- N.A.	
Nuisances	- stress, health concerns	- vicinity	- rare to frequent	- complaints, perception studies	Étude exploratoire sur exposition aux organo-phosphorés et risques pour la santé, DSP, Montérégie, 1997
	- quality of life, disturbance	- vicinity	- rare	- complaints	
Indirect impacts or other exposure	acute: blurred vision, stomach pains, nausea, dizziness, nervousness, various central nervous system disorders	handlers of concentrated solutions	- rare	- medical report, public security	Guide "Pesticides et agriculture; bon sens, bonnes pratiques (DEW, DHSS, DAFF, UPA) Keifer (1997

References

Boudreault, D., D. Belleville, and G. Carrier (1997) L'épandage d'insecticides dans les vergers en Montérégie. BISE (Bulletin d'information en santé environnementale), 8(4): 1-3

Chagnon, M., A. Payette (1990 Modes alternatifs de répression des insectes dans les agro-écosystèmes québécois, Tome 1, Department of the Environment and Wildlife, Centre québécois de valorisation de la biomasse, 81 p.

Chevalier, P. (1993) Gestion des ressources renouvelables : secteurs agricole et forestier. Presses de l'Université du Québec, 558 p.

Dionne, S., S. Picard, and N. Lafrance (1997) Profil sectoriel de l'industrie bioalimentaire au Québec (1996 Edition). Department of Agriculture, Fisheries and Food, Government of Quebec, 83 p.

EXTOXNET: http://ace.ace.orst.edu/info/extoxnet/pips/gnindex.html

Department of Agriculture, Fisheries and Food, Department of the Environment and Wildlife, and Department of Health and Social Services (1996) Pesticides et agriculture. Les Publications du Québec, Government of Quebec, 60 p.

Giroux, I. (1997) Suivi environnemental des pesticides dans des régions de vergers. Department of the Environment and Wildlife, Government of Quebec, __ p.

Grégoire, F. (1997) Bilan des ventes de pesticides au Québec en 1995. Department of the Environment and Wildlife, Government of Quebec, 88 p.

Keifer, M. C., Editor(1997) Human health effects of pesticides. Occupational Medicine: state of the art reviews, 12(2) 203-411 p.

Lowenhertz, C., R. A. Fenske, N. J. Simcox, G. Bellamy, and D. Kalman (1997) Biological monitoring of organophosphorus pesticide exposure among children of agricultural workers in central Washington State. Environment Health Perspective, 105: 1344-1353.

Department of the Environment and Wildlife (1997) Étude exploratoire sur la présence de pesticides dans l'air ambiant et au sol à proximité des vergers, région de la Montérégie, Government of Quebec, _ p.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 8 of 11

Waste management

The management of household waste has become one of the most important environmental issues of the latter part of this century, both in industrialized and developing nations. Following the Second World War, with the reduction of the life cycle of consumer goods and the unrestrained use of natural resources by industrialized nations, there was an increase in the harvesting of the world's resources, to produce more and more consumer items. Waste reduction, reuse, recycling and recovery are obviously approaches that will help slow down the depletion of natural resources, while simultaneously contributing to a reduction in landfilling and incineration, two waste management methods currently popular in industrialized societies.

Canadian perspective

Canada is one of the world's major producers of municipal solid waste, producing over 1,000 kg of waste per capita each year (including commercial and construction waste). The typical garbage bag in a municipal household in Canada contains by weight 25 to 40% paper and cardboard, 20 to 35% of putrescible organic matter or green waste, about 10% of glass, about 8% of plastic and 5 to 12% of metals.

In Canada, in 1992, 78% of this waste was disposed of by landfill and 5% by incineration. The remaining 17% were recycled or composted, representing a significant improvement compared to the 6% value registered in 1988. This improvement is due in part to the implementation of initiatives proposed by the Canadian Council of Ministers of the Environment (CCME), whose objective was a 50% reduction in total waste production before the end of the century. In addition to urging recovery at the municipal level, these initiatives also targeted packaging. In fact, waste from packaging was reduced by 25% between 1988 and 1993. It should be mentioned also that the annual costs for waste disposal, including pick-up and transportation, are estimated at over $3 billion (data for 1995). This does not include the environmental and social costs (negative externalities) associated with this loss of resources.

References

Environment Canada (1996) The State of the Environment in Canada, Part III, Chapter 12. Department of the Environment, Government of Canada.

Quebec perspective

The type and quantity of waste produced in Quebec are similar to that of other regions. According to data from Recyc-Québec, the industrial and commercial sectors recycle about 35% of their waste, but in the household sector, the percentage is only 17%. Over 95% of unrecovered waste is eliminated in 553 landfill sites. The rest is eliminated in the three incinerators that are still in operation. Despite the existence of the Regulation Respecting Solid Waste (implemented in 1978), many landfill sites still do not comply with standards, and there are still dump sites that are completely illegal. Since the implementation in 1995 of an Act Respecting the Establishment and Enlargement of Certain Waste Elimination Sites, all disposal projects must be submitted to the environmental impact assessment and review process. It should be mentioned also that the report of the Panel on Waste Management in Quebec, tabled in 1997, redefined waste management, especially by promoting the 4 R's. However, the Department of the Environment and Wildlife has yet to make the recommendations of this report official government policy.

Environmental assessment of waste management projects

The environmental impacts of waste management depend on the type and quantity of the waste to be processed, on the site and on the disposal methods. The environmental assessment must also cover the environmental parameters of the site and weather conditions, and must address the worst-case scenario where pollutants are released into the environment and can affect a community. Public health is generally the major issue in environmental assessments targeting waste management projects.

Finally, waste recovery, reuse, recycling and composting projects are not included in the environmental impact assessment process. Selective collection projects are also excluded. The only projects dealing with some type of waste recovery that have been evaluated in Quebec are cogeneration initiatives, or the enhancement of waste for energy production, such as forest or cellulosic waste, hazardous organic waste, tires and used oil. These usually involve incineration processes used by power plants and cement factories to produce energy.

References

BAPE (1997) Déchets d'hier, ressources de demain. Rapport de la Commission sur la gestion des matières résiduelles au Québec, 477 p. + appendices.

BAPE (1990) Les déchets dangereux au Québec. Rapport de la Commission d'enquête sur les déchets dangereux, Les Publications du Québec, 491 p.

Comité de santé environnementale (1993) Mieux vivre avec nos déchets. La gestion des déchets solides municipaux et la santé publique, 138 p.

An Act to Prohibit the Establishment or Enlargement of Certain Waste Elimination Sites (1995, c. 60)

An Act Respecting the Establishment and Enlargement of Certain Waste Elimination Sites (L.R.Q., cE-13.1)

Department of the Environment and Wildlife (1995) The sustainable and responsible management of waste. Public consultation document, 52 p.

Regulation Respecting Solid Waste: R.R.Q., 1981, cQ-2, 14

Landfilling

As mentioned above, landfilling is the most common method of waste management in Quebec and is used for 95% of total wastes produced. The 1978 regulation requires that sanitary landfilling be practiced in a manner that ensures the abatement of water and air pollution. Despite this regulation, there are still many landfill sites where various materials are disposed without taking into consideration the environmental impacts; they are operated without any monitoring. The purpose of sanitary landfilling is simple: confine garbage to a designated area. Disposal can be made by piling, by dumping into a trench (a hole is dug and then it is filled with successive layers of waste and inert and granular material such as soil) or by elimination in a quarry (an abandoned quarry is filled with waste; most of the waste from the City of Montreal is stored in the old Miron quarry, which ceased operations at the beginning of the 70s). It should be noted that all the sites used for disposal of dry material are former quarries.

Water pollution

Leachate, also called percolate, is the liquid produced by the biodegradation of waste and by the seepage of the water through waste. This water becomes loaded with microorganisms as well as organic and inorganic substances. It is difficult to determine beforehand what the leachate will contain because its composition depends on many factors such as the type of waste, the quantity of water, the type of landfilling operation, the thickness of the layer of waste, etc. Tests on percolated water from a landfill site in Quebec revealed a biochemical oxygen demand of 3,600 mg/L, suspended particulates with a concentration of 150 mg/L and a total coliform count varying between 1,800 and 2 million parts per deciliter (100 mL).

Local hydrogeological conditions and confinement or sealing methods are therefore major determining factors with respect to risks for the environment and for health. Surface and ground water may have been polluted and can become a hazard for the people using it. Landfill sites using the piling method and located near a stream or river represent a significant risk for water quality. There are also some streams whose coloration reveals some type of pollution. As for underground water, potential impacts can be assessed only if the properties of the water table and the geological properties of the soil have been fully determined.

Leachate has to be recovered and processed to prevent water contamination. For any new landfill site, it is therefore necessary to ensure that there is no leakage, and the leachate has to be pumped to a water treatment plant. It should be mentioned here that existing regulations only provide that the leachate meet certain chemical and microbiological requirements before being released into the environment (Q-2, r.14, a.30). At present, there is no requirement to assess the overall ecotoxicological effects of leachate, despite the fact that certified tests are currently available.

Air pollution

Biogas is a source of air pollution originating in sanitary landfill sites (open-air waste burning is usually prohibited, although it is tolerated in northern regions). Biogas, a byproduct from a landfill site, is created by the anaerobic decomposition of organic matter by various microorganisms. This decomposition produces various organic volatile substances. Typical biogas contains between 45 to 60% of methane (CH_4) and between 35 and 50% of CO_2, the remaining substances being nitrogen, various gases, and also sulphur and volatile organic compounds (VOC) that are generally quite smelly. Biogas can also be explosive because of the presence of methane. In fact, pressure created by biogas inside the accumulated waste material forces the gas to the surface through preferred flow channels. If an airtight cover is placed over a landfill site, or if such a site is compacted, the gas may be directed horizontally toward closed structures such as basements. In high concentrations, biogas can be asphyxiating.

The California Air Resource Board and EPA have analyzed the properties of biogases at several landfill sites. Their studies reveal that in addition to the risk of asphyxia or explosion when methane is present, VOCs constitute a significant health risk. It should be pointed out that cancer-causing compounds such as benzene and polyvinyl chloride can also be present. Studies conducted on dispersion characteristics reveal in some instances cancer risk levels exceeding the acceptable limit (1×10^5), especially in disposal sites for hazardous waste.

In Quebec, there are no regulations targeting biogas emissions, and these are only superficially mentioned in the regulations respecting hazardous material that were implemented in December 1997. However, in 1996, the government authorized the enlargement of the Lachenaie sanitary landfill on the condition that all biogases be captured and treated.

Sector: Waste Activity: Sanitary Landfilling

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- fire	- dust-laden smoke/deposits	- plume dispersion	- covering	- prohibit fires
	- explosion	- destruction	- site and perimeter	- biogas management, site leakage prevention	- daily covering when not stipulated in any law
Gaseous or air emissions	- biogas - methane (CH_4)	- greenhouse effect	- world-wide	For all these pollutants: promotion of use for energy production	- gas detection for CH_4.
	- carbon dioxide (CO_2)	- greenhouse effect	- world-wide		- none
	- VOC	- pollution by ground-level ozone	- local and regional		- none
Liquid emissions or discharge into water	- leachate BOD, COD	for all these pollutants: disturbance of marine life, pollution of surface and underground waters	from local to several kilometres	- solid waste: migration/seep-age <300m/5 years -hazardous waste: various membranes depending on speed of migration	capture and treatment of leachates to comply with emission standards
	- various hydrocarbons				
	- heavy metals				
	- various micro-organisms				
Solid emissions or discharge into the soil	- airborne waste	- appearance	- air/ground perimeter	litter fence, daily covering, reduction in waste handling operations	3 m high and 20 m from the landfill site - Aspergillus <10,000 ufc - extermination
	- mold	- unhealthy conditions	- community		
	- vermin	- unhealthy conditions	- community		
Nuisances	- noise	- unhealthy conditions	vicinity and community	- buffer zone	10 m (width of buffer zone); covering with 20 cm of soil
	- odour	- unhealthy conditions		- buffer zone and daily covering	
Indirect impacts or other exposure	devaluation and price downgrading	economic	community	monetary and social compensation, communications	impact assessment (Q-2, Section IV.1)

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Technological disaster	- nose-throat irritation, asphyxia, skin burning	vicinity and workers	- high	- fire and injury reports	http://www.cfe.cornell.edu/wmi/ USEPA (1988) Q-2, r. 14 to 59
	- traumas, deaths		- 31 cases in the USA between 1967 and 1987	- morbidity/mortality gas detection	
Gaseous or air emissions	- asphyxia, injuries	vicinity and workers (especially in enclosed areas)	- occasional (vicinity), high (workers)	- gas detection (<1.25% per vol.)	CCME (1989) Comité de santé environnementale (1993) California Air Resource Board
	climate changes for CH_4 and CO_2			- atmospheric CO_2	
	- cancer		- very low	- benzene and dichloroethane levels, and total VOCs	
Liquid emissions or discharge into water	unhealthy conditions, acute or chronic poisoning; cancer-causing effects, possibility of teratogens or mutagens	people swimming or consuming contaminated water; vulnerable people are mostly children	acute poisoning: rare chronic poisoning: few reported cases	monitoring of various pollutants in leaching water and also in natural water receiving the discharges	- World Bank (1991) - American J. of Preventive Medicine 7(6): 352-362 (1991) - Q-2, r. 14 a. 29-30, order 1310-97, a.3
Solid emissions or discharge into the soil	- quality of life, hygiene	For all these pollutants: vicinity and community	- very high	- complaints	Lavoie and Marchand (1997) Q-2, r. 14, a. 35 Q-2, r. 14, a. 42
	- infections, allergies		- high	- Aspergillus <10,000 ufc	
	- spreading of various diseases		- very low to low	- epidemics, inspections	
Nuisances	- sleep quality	vicinity and community	- very high	- L_{eq} 8 hrs per night, 45 dB(A)	Létourneau, M., Le bruit communautaire, MEF, 39 p. - Gingras, B. (1997), BISE 7(5) 1-3
	- stress		- very high	- complaints/ perception	
Indirect impacts or other exposure	assessment/ roperty taxes individual and collective stress	vicinity and community	occasional to very high	monitoring property assessments, perception studies	- Impacts psychosociaux inhérents à l'exploitation d'un LES, DSP, PRSSS Estrie, Oct. 94 - Archives of Environmental Health 50(2): 95-102

References

Briggs, J. L., and J. W. Huges (1990) Using risk-based algorithms in a landfill risk analysis. Waste Age, March 1990: 32-4, 146

California Air Resources Board (1989) The Landfill Gas Testing Program: A Second Report to California Legislative. Stationary Source Division, Sacramento, CA, various pages

Comité de santé environnementale (1993) Mieux vivre avec nos déchets. La gestion des déchets solides municipaux et la santé publique, 138 p.

Drouin, L., N. Richer, and M. Goldberg (1992) Risques associés au biogaz des sites d'enfouissement sanitaire. Presentation at the 4th symposium on environmental health, October 1992, Quebec, 24 p.

Environment Canada (1996) The State of the Environment in Canada, Part III, Chapter 12. Department of the Environment, Government of Canada.

EPA (1991) Air emissions from municipal solid waste landfill. Background information for proposed standards and guidelines. Environmental Protection Agency, report no. EPA/450/3-90/011A, 544 p.

Frigon, J. C., J. L. Bisaillon, L. Paquette, and R. Beaupré (1992) Caractérisation et traitement du lixiviat d'un lieu d'enfouissement sanitaire. Sciences et techniques de l'eau, November, p. 469-474.

Lavoie, J., and G. Marchand (1997) Détermination des caractéristiques à considérer d'un point de vue de santé et sécurité des travailleurs dans les centres de compostage des déchets domestiques. Quebec Occupational Health and Safety Research Institute, R-159 (June 1997), 37 p.

Department of the Environment and Wildlife (1995) Pour une gestion durable et responsable de nos matières résiduelles. Government of Quebec, 52 p. + appendices.

Poulsen, O. M. *et al* (1995) Sorting and recycling of domestic value; review of occupational health problems and their possible causes. The Science of the Total Environment, 168: 33-56

Regulations Respecting Solid Waste; R.R.Q., 1981, cQ-2, r.14

Van Collie, R. *et al* (1990) Integrated ecotoxicologial evaluation of effluents from dump sites. Advances in Environmental Science and Technology, Academic Press, New York, 22(12): 161-191.

World Bank (1991) Environmental Assessment Sourcebook. World Bank Technical Paper 140, Volume II: 208-256

Incineration

Generally, airborne emissions from waste incineration are quite visible, and reaction from the public is often swift, even if less than 5% of waste produced in Quebec is incinerated. Carbon dioxide and water are the main products resulting from waste incineration. The other substances, produced mostly by the incineration of inorganic compounds, are transformed into ashes that are then buried.

The combustion fumes include gases, particles and flyash, which is made up of small, easily airborne particles which penetrate deeply into the respiratory tract. The particles and flyash can be inert matter, such as silica, but may also include various metals that have become vaporized. Carcinogenic metals, especially cadmium and chromium, generally represent greater risks (slightly under 1×10^5, which is less than one case of cancer for 100,000 persons exposed). Considerable amounts of mercury and lead are also released and these heavy metals are toxic.

Some substances that have not been completely incinerated can concentrate on particles and these substances can also be found in gaseous form in the smoke. Other gases that can be identified in incinerator fumes are volatile organic compounds (VOC), polychlorinated biphenyls (BPC), polycyclic aromatic hydrocarbons (PAH), and especially dioxins and furans. The literature suggests that in general, there is no significant increase in the risk of cancer when the incinerators are operated to standards. It is estimated that the extra absorption of dioxins and furans, in the worst-case scenario as found in the vicinity of the Carrières incinerator in Montreal, represents only 5% of the input provided by "background noise", which is predominantly from food sources.

Incinerator smoke also contains many other gases such as sulphur dioxide and chlorinated compounds. At normal levels, these substances are not considered likely to produce harmful effects as such on the environment and health. However, they do represent an addition to other pollutants that cause climatic changes and destroy the ozone layer, and these substances are also a cause of acid rain and urban smog.

The solid waste resulting from incineration is made up of heavy grill ashes (that cannot become airborne), and these form most of the solid waste from incineration (95%). In general, they are non-toxic, and are usually disposed of at landfill sites. However, these ashes contain various substances that can be a concern and they require careful management, as in the case of hazardous waste. In some countries, they are used in road building and also for backfilling.

Sector: Waste **Activity: Incineration**

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- fires and explosions	air pollution from smoke, destruction	air and water, locally and regionally	technical controls, emergency measures, confinement	Department of the Environment, CSST, Emergency preparedness, municipalities
Gaseous or air emissions	- carbon dioxide (CO_2)	- greenhouse effect	- world-wide	- none	-Rio (1992) and Kyoto (1997) commitments
	- carbon monoxide (CO)	- negligible	- local	- combustion control	- 13 ppm (8 hrs) Q-2 Reg. Qual. Atmosph.
	- nitrogen dioxide (NO_2)	- acid rain, ground level ozone	- local to continental	- none	- 0.2 ppm (1hr) and 0.1 ppm (24 hrs), Q-2 Reg. Qual. Atmosph.
	- sulphur dioxide (SO_2)	- acid rain, smog	- local to continental	- gas cleaning	- 0.5 ppm (1hr) and 0.1 ppm (24 hrs), Q-2 Reg. Qual. Atmosph.
	- hydrogen chloride (HCL)	- acidification of the environment	- local to regional	- gas cleaning	- none
	- doxins, furans, PAH, benzene	- bioaccumulation in living organisms	- local to world-wide	- combustion temperature	- 0.5 mg/m^3 (TCDD) CCME, 99.99% destruction (EPA)
	- VOCs	- creation of ground-level ozone	- local to regional	- combustion performance	- ???
	- heavy metals (Pb, Hg, As, Cr, Cd)	- water and soil contamination	- mostly local	- flue gas cleansing	- none
Liquid emissions or discharge into water	- leaching water from ash disposal	- surface and ground water pollution	- local and regional	- prevention of leakage from disposal site	- incineration waste regulated by R4, a.6
Solid emissions or discharge into the soil	- fly ash and disposal of ash from racks	- pollution, mostly caused by more toxic flyash	-site and perimeter	- prevent fugitive emissions (dampen, contain)	- none
Nuisances	- noise	negligible impacts on the natural environment	- local	for all these nuisances: buffer zones, etc.	- L_{eq} 45dB (nighttime)
	- appearance		- local		- none
	- odours		- local and regional		- municipal regulations
Indirect impacts or other exposure	- not in my backyard syndrome	degradation of the human environment	- local to regional	- education, public input	- environmental assessment process

STRESSOR/ EXPOSURE	**Effect on health**	**Population at risk**	**Probability of occurrence**	**Environment/ biological indicator (monitoring)**	**Information/ references**
Technological disaster	- traumas, injuries, deaths;	- workers, vicinity and community	- rare	- morbidity and mortality reports, fire department reports	
Gaseous or air emissions	- climatic change (injuries, deaths)	- world-wide	- high	- geoclimatic data and weather phenomena	Carrier *et al* (1991) Laflamme *et al* (1996 Minott (1989) Travis (1989) EPA (1983, 1989) Environment Canada (1991) CCME (1989)
	- ↑ carboxyhemo globinemia (cHB)	- workers	- very rare	- level of blood cHB	
	- irritation of respiratory tract	- vicinity	- rare	- atmospheric NO_2 level	
	- respiratory problems (asthma, bronchitis, etc.)	- mostly vicinity	- rare	- epidemiology of respiratory ailments	
	- respiratory irritations	- vicinity	- very rare	- epidemiology of respiratory ailments	
	- potential cancerogenic, mutagenic and teratogenic effects	- workers, residents under dispersion plume	- 0.3 to 21 cases per 10^6 persons exposed	- few indicators with the required sensitivities	
	- none at expected levels	- N.A.	- N.A.	- air emission tonnage	
	- certain cancers (lung, leukemia) and neurotoxicity	- workers and vicinity (children) under the plume	- rare or insignificant	- air content determination, epidemiological studies	
Liquid emissions or discharge into water	- neurotoxicity, possibility of some cancers	- users of drinking water	- very rare	- surface and ground water quality	
Solid emissions or discharge into the soil	- possible neurotoxicity due to lead	- especially children in vicinity	- rare	- lead detected in the soil	
Nuisances	- sleep disturbance, stress	- vicinity	- occasional	- noise levels L_{eq} (8 hrs), 45 dB, nighttime	DEW (1993) Le bruit communautaire, 39 p. Gingras, B. (1997), BISE, 7(5) 1-3
	- quality of life	- vicinity	- occasional	- perception studies "focus group"	
	- environmental allergy	- vicinity	- occasional	- perception studies, assessment of odors	

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Indirect impacts or other exposure	individual and collective stress, conflicts, economic losses	community	occasional	"focus group", property assessment	http://atsdr1.cdc.gov.8080/atsdrhome.html

References

Blais, F., and J.-L. Sasseville (1997) Analyse technico-économique des procédés de décontamination des boues d'épuration municipales. Vecteur Environnement, 30(3): 25-38.

Carrier, G., L. Lefebvre, M. Beausoleil, and M. C. Boivin (1991) Analyse des impacts des émissions de polluants produits par l'incinérateur des Carrières dans l'air ambiant sur la santé de la population. Département de santé communautaire Maisonneuve-Rosement. 54 p.

CCME (1989) Operating and Emission Guidelines for Municipal Solid Waste Incinerators. Canadian Council of Ministers of the Environment, Report TS/WM-ZTRE003, 39 p.

Comité de santé environnementale (1993) Mieux vivre avec nos déchets. La gestion des déchets solides municipaux et la santé publique, 138 p.

Couture, P., and M. Dupont (1997) Histoire de boues. Vecteur Environnement, 30(3): 16-22.

Environment Canada (1991) Analyse des impacts des émissions de polluants produits par l'incinérateur Des Carrières dans l'air ambiant sur la santé de la population, 27 p.

Environment Canada (1996) The State of the Environment in Canada, Part III, Chapter 12. Department of the Environment, Government of Canada.

EPA (1983 and 1989) EPA Hazardous Waste Incineration Guidance Series, Vol. I-VI

Laflamme, P. *et al* (1996) Avis sur les risques à la santé de la population reliés aux émissions atmosphériques de l'incinérateur de la RIGDRSQ. DSPPE Chaudière-Appalaches, 37 p.

Minott, D. H. (1989) Comparative Risk Assessment of Energy-Recovery and Landfill Facilities. Journal of Resource Management and Technology, 17(1): 1-8

Regulation Respecting the Quality of the Atmosphere (R.R.Q., 1981, c.Q-2, Section XIX)

Sedman, R. M., J. R. Esparza (1991) Evaluation of the public health risks associated with semivolatile metals and dioxin emissions from hazardous waste incinerators. Environmental Health Perspectives, 94 (August), 181 p.

Travis, C., S. C. Cook (1989) Hazardous Waste Incineration and Human Health. CRC Press Inc., 154 p.

Travis, C., H. R. Hattemer-Frey (1991) Health Effects of Municipal Waste Incineration. CRC Press, 387 p.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2
Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 9 of 11

Sewage sludge management

Use of municipal sewage sludge

Municipal sewage

A typical North American city produces from 225 to 380 litres of wastewater per person per day. The volume increases with population, since this figure also includes sewage from industrial and commercial establishments that are more numerous in large cities.

Municipal wastewater contains only 0.1% of pollutants in the form of solids and chemicals. Close to 70% of the pollutants occur in the form of organic compounds and 30% in the form of inorganic compounds. The concentration of total suspended solids (TSS), comprising both inorganics and organics, usually ranges between 100 and 400 mg/L, while the biological oxygen demand (BOD_5), basically a measure of the concentration of organics, also ranges between 100 and 400 mg/L. Phosphorus levels may be as a high as 15 mg/L. In addition to these pollutants, municipal sewage contains variable amounts of synthetic chemicals (solvents, PCBs, acids, etc.) from industries and businesses, along with many different types of microorganisms, particularly coliform bacteria, viruses and some parasites, such as protozoa and helminths. A significant quantity of these pollutants are also found in sewage sludge.

Origin of sewage sludge

Although sludge is generated at each stage of the treatment process, most of it is produced during primary and secondary treatment. During preliminary treatment, the water flows through screens that remove coarse materials such as plastics, tissues and pieces of wood, before being sent into a grit chamber where sand and other fairly dense particles are allowed to settle. Subsequently, the scum (oil and greases that are less dense than water and float on the top) is skimmed off. Primary treatment, carried out basically in settling tanks, removes total suspended solids (TSS) between 0.05 and 1.0 mm in size. The main purpose of secondary treatment (also known as biological treatment) is to remove any organic matter that was not removed in the settling process in the primary stage. Several different techniques are used, essentially based on digestion by aerobic or anaerobic bacteria, which metabolize the material. However, bacterial action also increases the volume of microorganisms at the bottom of the tanks, a significant portion of the sludge. The average volume of sludge produced in all stages of the process combined are 150 kg of dry solids per 1,000 m^3 of treated wastewater.

Sludge treatment

Raw sludge usually consists of over 95% water. It must be treated using several different processes to reduce the water content and stabilize it biologically.

The water content of sludge is reduced through thickening and dewatering. Thickening generally involves the use of mechanical processes (rotary drums) and gravity belts. Dewatering can be carried out using centrifuges, various screening equipment or thermal conditioning. This produces sludge with a water content as low as 10%. However, most sewage treatment plants produce sludge with a water content no lower than 50%, since reducing the water content further is costly. It is important to note that the concentration of non-biological pollutants usually increases as the solids content increases.

The purpose of stabilization is to reduce the fermentability of the organic matter in the raw (non-dewatered) sludge and to reduce the concentration of pathogenic microorganisms. Stabilization can be done through anaerobic or aerobic digestion, in which fresh organic matter (proteins, lipids, complex sugars, etc.) is broken down into simple substances (amino acids, fatty acids and simple sugars) and ultimately into mineral compounds (nitrates, ammonia, carbon dioxide, methane, phosphates, etc.) that do not support the development of an abundant microflora. Composting provides partial fermentation, reducing the concentration of fresh organic matter and eliminating most pathogens through heat under sufficiently high temperatures (55–70°C). Stabilization can also be done through chemical means: although the concentration of organics is not reduced, the reactants involved (notably quicklime, which increases the pH and the temperature) have a bactericidal effect.

Public health risks

The increasingly widespread use of sewage sludge as agricultural and tree fertilizers poses a public health risk. It is expected that over 180,000 t of sewage sludge, in the form of dry solids, will be generated in Quebec in the year 2000. Sludge contains key nutrients for plants, such as nitrogen and phosphorus, and can therefore be used in agriculture. Sludge can also be used as an organic and lime soil amendment. Sludge can therefore be used in silvicultural applications, particularly in tree nurseries, and on some types of agricultural land. However, some safety measures are needed; refer to the guides published by the Quebec Department of the Environment and Wildlife, on the use of sludge as a resource, for more information on the measures required.

Typical composition of sludge and health risks

Typical sewage sludge contains a wide variety of organic and inorganic substances. The pollution risks posed - and ultimately its toxic and pathogenic potential - depend on the presence or absence of the groups of pollutants described briefly in the following paragraphs.

Inorganic compounds

The inorganic compounds usually found in sewage sludge include nitrogen, phosphorus, potassium, calcium, magnesium and heavy metals.

Nitrogen concentrations range between 1% and 5% of dry weight. Before stabilization, most of the nitrogen occurs in organic form (proteins and amino acids). After stabilization, however, most of the remaining nitrogen (a significant proportion may volatilize during the process) is inorganic, either ammonia nitrogen (anaerobic stabilization) or nitrates or nitrites (aerobic stabilization). The presence of nitrates and nitrites in well water in total concentrations over 10 mg/L is a known health risk. When ingested, these pollutants may lead to the formation of methaemoglobin in the blood, or of nitrite or nitrosamine derivatives, the last two of which are well-known carcinogens.

Total phosphorus accounts for 1% to 4% of sewage sludge by dry weight. It is most common in inorganic form (50–75%) in both raw and stabilized sludge. When sludge is spread on fields, surface waters may be contaminated by phosphorus. This poses little risk to public health, except in the case of overfertilization, where phosphorus is transported by surface waters.

Elements such as potassium, calcium and magnesium all make up less than 1% of the dry weight of sludge. However, when sludge is chemically stabilized by liming, calcium concentrations may reach 25% of dry weight. These elements do pose public health concerns.

Sludge contains varying levels of heavy metals (Al, As, B, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se and Zn), with manganese and copper being the most abundant in a typical sludge formed by taking the average of several samples. The presence of these two metals is due mainly to the presence of industrial effluents as well as stormwater runoff from streets and industrial and commercial land. Cadmium, mercury and lead pose the greatest concern, because they are highly toxic. Copper, chromium, nickel and zinc are also believed to represent a significant risk. However, the concentrations of these metals in the sewage sludge in Quebec are generally below the levels considered hazardous by the EPA. Furthermore, heavy metals are not very mobile in the soil and there is no detectable contamination after sludge is spread on agricultural or forest land. However, a risk of contamination of forest fauna by cadmium and zinc has been reported. Some studies also suggest that aluminium poses a hazard (in its role in Alzheimer's disease) but the results so far are not conclusive. The potential risk associated with aluminum may call into question the practice of using alum (aluminum potassium sulfate) as a flocculant in wastewater treatment.

Organic compounds

For the purposes of this discussion, organic compounds can be divided into nontoxic and toxic substances. Of the two, nontoxic compounds are most prevalent, comprising all materials of plant or animal origin, including proteins, amino acids, sugars and fats. These materials are present in fecal matter as well as in some kitchen and food industry waste. Although most oils and greases from non-food industries could also be included in this category, some can be quite toxic. The biological oxygen demand (BOD_5) associated with these substances shows that they tend to be polluting; increased BOD substantially reduces the amount of oxygen available for aquatic organisms. In stabilized sludge, the quantity of biodegradable nontoxic organic matter is reduced by microbial action.

Toxic organic compounds are very diverse by nature, comprising hundreds if not thousands of substances. The most prevalent groups in sewage sludge include polycyclic aromatic hydrocarbons (PAHs), pesticides, halogenated aliphatic compounds, PCBs, chlorobenzenes, volatile organic compounds (VOCs), phenols, dioxins and furans. Phtalates, surfactants (particularly nonylphenols and alkylbenzenes), chlorobenzenes and some PAHs are present in stabilized sludge at concentrations of over 10 mg/kg (and as high as 100 mg/kg). Phtalates, which are commonly used in manufacturing adhesives, glues and lubricants, are found in very high concentrations. The high concentration of surfactants is due to their use in laundry detergents and many cleaning products.

Certain PCBs, PAHs, organochlorines and dioxins are known to be carcinogenic. However, they usually occur in very small concentrations in sludge and, after sludge has been spread, they are not believed to pose any real health risks. Phtalates and some surfactants (nonylphenols) are not considered highly toxic, although some studies suggest that they may disrupt hormone cycles regulating reproduction in mammals, even at very low concentrations. These results are not considered conclusive, however, and more studies are required.

Pathogens

Sewage sludge contains numerous microorganisms of varying pathogenicity, mainly parasites, viruses, bacteria and fungi.

Parasites of interest from a public heath perspective include protozoa, such as amoebae, *Toxoplasma gondii*, *Giardia lamblia* and *Cryptosporidium* spp., as well as helminths, such as *Ascaris* spp., *Trichuris* spp. and *Taenia* spp. These parasites may occur in sludge in the form of cysts or eggs, in numbers ranging from several hundred to a few thousand per kilogram. These numbers are high considering that infection can occur with the ingestion of as little as one cyst (in *Giardia* spp. for example). Eggs and cysts in sludge are very persistent and heat treatment at a temperature of at least 70°C is required to destroy them. After the sludge has been spread, some eggs or cysts may survive for several years in the soil. The health risks are mainly for workers on the site where the sludge has been applied.

Raw sludge may contain up to 1,000 viruses per gram. Stabilization can reduce that number by a factor of 10. Many viruses are found in sewage sludge, but the most prevalent are enteroviruses, such as the hepatitis A virus, which infect the digestive system. Some viruses can survive in the first 5 to 15 cm of soil for several months. Viruses are not very mobile, however, which limits the risks of water contamination.

Similarly, the most common bacteria in sewage sludge are the enteric bacteria (coliforms, shigellae, vibrios, etc.). Also present are bacteria of the genera *Streptococcus*, *Clostridium*, *Mycobacterium* and *Listeria*. The presence of a given pathogen (*Salmonella*, for example) depends on the prevalence of active or healthy (asymptomatic) carriers in the population. The number of bacteria from each of these genera in sludge varies. In general, a total coliform count of 10^8 to 10^9 can be found per gram of dry weight, while fecal coliform bacteria generally represent 10^6 to 10^7/g dry weight. *Salmonella* spp. represent from 10^2 to 0^3 g/dry weight; however, the infectivity of this genus is very high (1 to 6 cells), and when it is present at all, this is significant. In general, bacteria are able to survive in the ground for several months; some may be partially inactivated by below-freezing temperatures or a summer drought. However, it is recommended that farmers wait a full year (at a minimum, an entire summer) before using fields that have been treated.

Little research has been done on fungi (yeasts and moulds) in sewage sludge. However, it is known that a number of pathogens, including *Aspergillus fumigatus*, *Candida albicans* and *Cryptococcus neoformans*, are present. Since infection in humans occurs through direct contact or inhalation, those mainly at risk are workers handling sludge, which usually occurs during composting operations.

Air pollution

Some volatile organic compounds (VOCs) are released into the atmosphere following land application of sludge. Substances like benzene, chloroform, toluene, xylene and trichloroethylene largely evaporate within 48 hours of land application of sludge. However, substances like PAHs and PCBs do not evaporate to any significant extent. The health risk associated with VOCs resulting from land application of sewage sludge has not been established, but is generally believed to be low. The presence of fungal and bacterial spores and viruses in the air cannot be overlooked, but the main risk is probably to workers who apply the sludge or who move about on the treated site.

Water pollution

Most of the organic compounds in sewage sludge do not migrate into surface or ground waters because they are hydrophobic (e.g., PCBs, PAHs, organochlorines) and are well adsorbed by the soil. Although some pesticides and soluble substances like surfactants (nonylphenols) and chlorobenzenes leach into surface and ground waters to a large extent, the risk of water contamination is considered low or has not been established for the general population.

Heavy metals have been detected in water, but at concentrations lower than those thought to be of concern. However, contamination of surface waters and the water table by various forms of nitrogen (particularly nitrates) poses a real risk, particularly if excessive quantities are applied. Compliance with the Quebec Department of the Environment's standards respecting the land application of sludge will minimize the risk of water contamination by nitrogen. Phosphorus does not pose a risk of water contamination because it is retained to a large degree in the soil.

Soil pollution

Most pollutants present in sewage sludge find their way into the soil during land application, where they bind, with various degrees of reversibility, to soil components such as sand, loam and humus. Most synthetic organic compounds, even the most toxic ones like dioxins, are usually broken down by soil microorganisms in a relatively short time. Annual land application of sludge appears to lead to long-term accumulations of surfactants, given the high concentrations at which they are found in sludge. However, further research is needed.

Metals are usually not metabolized by soil microorganisms and, if they are not mobile, will persist in the soil. One important issue regarding metals in sludge is their absorption by plants. However, the rate of absorption by plants appears low, and the risk has been deemed minimal for consumers of the plants.

Nitrogen and phosphorus are essential nutrients for plants. When present in the soil, they are usually taken up by the plants for their growth. Therefore, the presence of these elements is of no concern, except where excessive concentrations result in leaching of nitrogen to the water table.

Finally, the presence of pathogenic microorganisms in the soil poses no public health risks. Most pathogens have a short lifespan and their persistent forms (spores, cysts, eggs) remain in the soil. Therefore, the risk is to people handling the soil in question, not to neighbouring communities.

Sector: Sewage sludge Activity: Land application of municipal sewage sludge

STRESSOR/ EXPOSURE	Nature of stressor	Impact on environment	Zone of influence	Control measures	Standards or recommendations
Technological disaster					
Gas or atmospheric emissions	- VOCs (mainly benzene, toluene, PAHs, chloroform (trihalomethane-THM), etc.	- pollution, smog- and ground-level ozone formation	- surroundings and region (for smog and ozone formation)	- worked into soil instead of spread on surface	- benzene: 30 mg/
	- fungal spores (*Aspergillus*, *Candida*, *Cryotococcus* and others	(with NO_x) - pollution, unhealthiness	- surroundings	- same as above, but not very efficient	m^3 (QC workplace standards)[24] - Aspergillus: <10,000 cfu
Liquid effluent or in water	- heavy metals	- toxic to aquatic organisms	Receptor watercourses. Distance varies depending on many different parameters: concentration and solubility of pollutants, temperature, spreading method, etc.	- Respect protective riparian strips, slope of terrain, do no spread in winter, stabilize sludge before spreading, etc. -For micro-organisms, preliminary heat treatment of sludge may be effective	see note [25] Al: < 0.1 mg/L (Alzheimer's) - THM: 350 μg/L (Q-2. Reg. on potable water[26] - 3 - 7 mg/L (MEF criteria for untreated water to be chlorinated - none - fecal coli.: 0 total coliform: 10/100 mL (Q-2 Reg. potable water)
	- synthetic organic compounds: mainly surfactants (nonylphenols), chlorophenols, THM	- disrupt reproduction (surfactants) carcinogenic: THM			
	- degradable organic compounds (proteins, amino acids, etc.)	- reduction in dissolved oxygen in water			
	- eggs and cysts of parasites: *Giardia*, *Toxoplasma*, *Cryptosporidium*, *Taenia*	- unhealthiness			
	- enteric bacteria: *Salmonella*, *Shigella*, *Vibrio*	- unhealthiness			
	- enteric viruses				
Solid emissions or in the soil	- heavy metals	Soil pollution, unhealthiness	Usually most of these pollutants not very mobile when spread	Do not spread too often on same site	- see note 2 - PCBs: 0.02-0.07 μg/kg.d (EPA); dioxin (TCDD): 10^{-6}μg/kg.d ATSDR - none - none
	- heavy or hydrophobic organic compounds (PCBs, PAHs, dioxins, etc.)	Extent of pollution depends on content of sludge and quantity spread			
	- eggs and cysts of parasites (see above)				
	-enteric viruses				
Nuisance	odours insects, vermin	unhealthiness	site and surroundings	buffer zone stabilization of sludge	municipal bylaws

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[24] Acceptable daily intake (μg/kg-d) according to EPA: toluene 200; chloroform 10; PAHs 40-300

[25] Acceptable concentrations in potable water (μg/L) according to Quebec Potable Water Regulation and acceptable daily intake (μg/kg-d) according to EPA: As 50 and 0.3; Cd 5 and 0.5 ; Cr 50 and 5; Hg 1 and 0.3; Pb 50.

[26] This standard should drop to 100 μg/L when the regulation is revised in accordance with the new MPC from Health Canada.

Indirect impacts					

STRESSOR/ EXPOSURE	**Health effects**	**Population at risk**	**Probability of occurrence**	**Biological/ environmental indicators (monitoring)**	**Information/ references**
Technological disaster					
Gas or atmospheric emissions	- irritation of resp. tract, possible carcinogen	-mainly workers	- very rare	- VOCs in ambient air	Couillard *et al.* (1993) Labelle (1995)
	- allergies, resp. irritations, infections	- workers, maybe neighbours	- unknown	- cfu per m^3	
Liquid effluent or in water	- various toxic effects, possible carcinogen	- people consuming polluted water	- rare or unknown	For all pollutants concerned: determine concentration in runoff from treated area, analyze well water Epidemiological monitoring of local populations near places frequently treated	Couillard *et al.* (1993) Labelle (1995) Beauchemin *et al.* (1993) Dubé and Delisle (1995) Colborn *et al.* (1996) (for surfactants and nonylphenols)
	- trihalomethanes, carcinogenic; nonyl-phenols disturb hormone cycles and reproductive system	-people consuming polluted water	- rare or unknown		
	-unhealthiness, no direct effect, formation of THM if water chlorinated	-people consuming polluted water	- rare or unknown		
	- various types of parasitosis	-people consuming polluted water	- rare or unknown		
	- mostly gastro-enteritis	-people consuming polluted water	- rare or unknown		
	- gastroenteritis	-people consuming polluted water	- unknown		
Solid emissions or in the soil	- see above	- workers	- unknown	For all soil pollutants: determine whether most dangerous are present. Monitor workers if necessary.	Beauchemin *et al.* (1993) Labelle (1996) Couillard *et al.* (1993)
	- carcinogenic	- workers	- unknown		
	- various types of parasitosis	- workers	- unknown		
	- gastroenteritis	- workers	-unknown		
Nuisance	- quality of life	- neighbourhood and community	- rare or unknown	- complaints, perception studies	
Indirect impacts					

References

Beauchemin, S., M.R Laverdière and C. Scraire (1993) *Revue de littérature sur les métaux, l'azote et le phosphore dans les boues d'origine municipale de pâtes et papiers et de désencrage en prévision de leur valorisation en milieux agricole et forestier.* Cogisol Inc. (produced for Quebec Department of Natural Resources), 112 p.

Chevalier, P. (1995) *Gestion de l'environnement en milieux urbain et industriel.* Presses de l'Université du Québec, 577 p.

Colborn, T., D. Dumanoski and J.P. Meyers (1996) Our stolen future. Dutton Books, 306 p.

Dubé, M. and S. Delisle (1995) *Suivi environnemental effectué à la suite de l'épandage de boues d'épuration des eaux usées municipales à la pépinière de Normandin.* Department of Natural Resources, Government of Quebec, 95 p.

Couillard, D., P. Chouinard and G. Mercier (1993) *Risques environnementaux associés à la présence de contaminants organiques de synthèse dans différentes boues résiduaires lors de leur valorisation en milieux agricole et forestier.* INRS-Eau, Université du Québec, 108 p.

Gossels, T.A. and J. D. Bricker (1994) Principles of clinical toxicology. Raven Press, Third edition, New York, 447 p.

Labelle, A. (1995) *Utilisation des boues d'usines d'épuration et risques à la santé. BISE (Bulletin d'information en santé environnementale)*, 6(3):__ - __.

Labelle, A. (1996) *Valorisation des boues d'épuration municipales; quels sont les risques de contamination? Direction de la santé publique Mauricie-Bois-Francs* 46 p.

Quebec Department of the Environment and Wildlife (1996) *Évaluation sylvicole, environnementale et technico-économique de la valorisation de trois types de boues de stations d'épuration municipales dans la région des Laurentides.* Department of the Environment and Wildlife (Government of Quebec), final report, 284 p.

Quebec Departments of the Environment and Wildlife and of Agriculture, Fisheries and Food (1991) *Valorisation agricole des boues de stations d'épurations des eaux usées municipales.* Quebec Departments of the Environment and Wildlife and Quebec Department of Agriculture, Fisheries and Food (Government of Quebec), 91 p.

Quebec Departments of the Environment and Wildlife and of Agriculture, Fisheries and Food (1991) *Valorisation sylvicole des boues de stations d'épurations des eaux usées municipales.* Quebec Departments of the Environment and Wildlife and Quebec Department of Agriculture, Fisheries and Food (Government of Quebec), 83 p.

Septic tank sludge

Individual sewage treatment systems are those that are not connected to a sewage system. The simplest way of containing fecal manner is the old-fashioned pit privy, a simple hole dug in the ground and covered over when full, which is still used by hundreds of millions of people around the world. One of the most highly evolved forms of individual sewage treatment is the septic tank, which is used in the industrialized world to treat domestic sewage from isolated residences. This sewage must be treated, because of its polluting nature. The typical effluent from a single-family house in North America contains around 450 mg/L of total suspended solids (TSS) and an organic load equivalent to a BOD_5 of 400 mg/L (this figure must be no higher than 3 mg/L to support aquatic life and 7 mg/L for untreated potable water destined for chlorination).

Septic tanks have become increasingly common for treating sewage from small businesses and industries. This sewage often contains pollutants not usually present in domestic sewage, such as synthetic organic compounds. However, there is not enough data to characterize this type of sludge. Thus the data given in this section concerns sludge from septic tanks used to treat household sewage.

How a septic system works

Sewage treatment in a septic system is a two-step process: first, the sewage is channelled into an underground tank with a volume of several thousand litres (between 1,500 and 5,000); the average residence time is two or three days. The partially treated sewage is then evacuated from the tank into the ground through perforated pipes under the surface. The soil acts as a purifier, having all the qualities needed to complete the treatment that began in the tank.

Septic tanks are installed underground and are usually made of concrete or fibreglass. They generally have two separate compartments through which the wastewater can flow. The tank is designed to allow suspended solids (SS) denser than water to settle out, while oils, greases and low density suspended solids accumulate on the surface to form the crust or scum. The water flows continually through the tank; the crust and the sediments forming the sludge must be pumped out regularly (every few years or so) to avoid overloading the system.

Microbial dynamics of septic tanks

As in larger municipal sewage treatment systems, in a septic tank, the raw organic matter that goes into the tank is digested by various microorganisms and thus stabilized.

A first group of facultative anaerobic and aerobic bacteria transforms the complex organic compounds (proteins, carbohydrates, lipids) into simple substances such as monosaccharides, amino acids and volatile fatty acids. A second group of bacteria, strict anaerobes, then transforms the primary metabolites into molecules such as carbon dioxide (CO_2), H_2, methane (CH_4) and hydrogen sulphide (H_2S). However, methane formation does not occur often in Quebec because methane bacteria grow very slowly at temperatures below 20°C. The gases produced form bubbles in the sludge and rise to the top, carrying with them solids which form a layer of scum at the top of the tank.

Mineralization of the organic matter generally occurs after a year in the tank. Methane production, if it occurs at all, does not begin until the second year if the tank has not been pumped out. Therefore, pumping out the tank every two years prevents the methanization process from occurring. However, regular pumping of the tank is required to prevent the sludge from overflowing into the tank's second compartment and into the disposal field; excessive TSS in the effluent from the tank will plug up the pipes that take the water to the disposal field.

It should also be noted that the penetrating, foul odour of sludge is caused by the products of anaerobic decomposition. Gases such as H_2S cause some of the odours, but volatile fatty acids, butyric acid and substances with a fecal odour, such as indole and skatole, are also to blame.

Quantity of sludge produced

Considerable research has been conducted on septic tank sludge production. Unfortunately, few studies have been carried out in Quebec, and data from the United States and Europe must be used. However, a similar trend is observed everywhere: annual accumulation of sludge decreases with time. During the first year of operation of a tank, the scum and sludge produced ranges from 80 to 180 litres per person, but falls to 40 to 100 litres after three years of operation. Pumping out the tank completely promotes greater sludge production the following year. The decrease in the accumulated sludge over time is a normal process inherent in anaerobic digestion, which gradually reduces the organic mass, mainly through bacterial autolysis. Anaerobic digestion takes some time to get established and as many as five years may be required before it reaches peak efficiency.

Sludge accumulation varies widely depending on various conditions. A low annual temperature promotes accumulation because of the slowing of bacterial activity responsible for breaking down the organic matter. At temperatures below 10°C, bacterial metabolism is almost completely inhibited, which means a significant increase in sludge accumulation during the winter. Furthermore, when the input of organic matter into the tank is high, sludge formation increases, while reduced water flow tends to result in decreased functioning of the tank.

It does not seem to be currently possible to determine the actual quantity of septic tank sludge produced annually in Quebec. There are approximately 400,000 permanent residences and 200,000 summer cottages that are not served by a sewage system. If all these dwellings were connected to a regulation septic tank that was pumped out every two years, as prescribed in the Quebec *Regulation Respecting Waste Water Disposal Systems for Isolated Dwellings* (Q-2, r.8), the volume of sludge produced would be 1,000,000 m^3 per year. However, given the fact that many tanks do not conform to standards and the rule of pumping out the tank every two years is not always respected, the volume of sludge pumped out of tanks every year in Quebec can be estimated at between 200,000 and 340,000 m^3 per year.

Composition of sludge

Domestic sludge consists of scum (a mixture of grease and floating suspended solids), sediments and water drawn from the tank when it is pumped out. Technically speaking, it is liquid anaerobic sludge since water makes up 95% to 98% of the sludge by weight. Aside from various non-decomposable solids (sand, pieces of plastic or metal, hair, etc.), the sludge consists essentially of a dark brown to black mass with no identifiable particles.

Septic tank sludge has a very high pollutant load, as shown by the following figures: a biological oxygen demand (BOD_5) of 5,000 to 10,000 mg/L; total suspended solids (TSS) of 20,000 to 40,000 mg/L; total nitrogen (N) of 100 to 1,000 mg/L; total phosphorus (P) of 30 to 300 mg/L. According to the data available, septic tank sludge contains no dangerous organic compounds, such as PCBs, PAHs or chlorinated organic compounds. However, surfactants from detergents, such as nonylphenols and alkylbenzenes, may be present, as well as phtalates, which are used in the manufacture of adhesives, glues and lubricants. However, the current scientific literature contains no studies in this regard.

When the tank is functioning normally, the pollutant load of the liquid discharged from the tank (effluent) is less than that of the sludge: BOD_5, 30–250 mg/L; TSS, 30– 200 mg/L; total N, 10–300 mg/L; and total P, 1–20 mg/L. As explained above, this effluent is discharged into a disposal field where the concentration of pollutants is reduced by the activity of soil microorganisms. The sludge pumped from the tanks has a high pollutant load, posing management problems.

Heavy metals

Heavy metals are found in small concentrations in septic tank sludge. They come mainly from domestic cleaning products and metal outflow pipes. The main metals found in septic tank sludge are iron (approximately 200 mg/L), aluminium (50–250 mg/L), zinc (around 35 mg/L) and copper (approximately 10 mg/L). These concentrations are well below the recommended values set out in the guide on the use of treated sludge in agriculture (i.e., Fe, 1000 mg/l; Zn, 500 mg/L; Cu, 100 mg/L), except for aluminium, for which the maximum allowable concentration is 100 mg/L. In Quebec, up to 1,380 mg/L of aluminium has been

found in septic tank sludge. In Quebec, the average arsenic concentration is 14.7 mg/L, with a maximum of 44 mg/L, which is much higher than levels in the United States (average of 0.16 mg and maximum of 0.5 mg). This raises the question of whether the Quebec sample is representative. However, the concentrations are below the maximum values set out in the above-mentioned guide, of 50 mg/l for inorganic arsenic and 100 mg/L for organic arsenic.

Microorganisms

The microorganisms found in septic tank sludge are similar to those in primary sludge from municipal wastewater treatment facilities. The main organisms identified and their concentrations (per 100 mL) are as follows: total coliforms, 10^7–10^9; fecal coliforms, 10^6–10^8; fecal streptococci, 10^6–10^7; anaerobic spore-forming bacteria (mainly *Clostridium* and *Bacteroides*), around 10^5; *Salmonella*, 1–100. A number of parasites are also found, such as *Ascaris* and *Trichuris*, as well as several viruses, including rotaviruses, the Norwalk virus and enteric adenoviruses.

Special precautions must therefore be taken in the handling and management of septic tank sludge, since it can cause a range of gastrointestinal infections, just like sludge from wastewater treatment plants (see section on "*Use of municipal sewage sludge" p.177*).

Management of septic tank sludge

Quebec has no management plan for septic tank sludge. However, dumping or using this sludge in any environment is unthinkable. Quebec Department of the Environment and Wildlife guidelines state that the regional county municipalities (RCM) are responsible for managing sludge to ensure that it is treated and disposed of at an acceptable final destination. It is preferable to reuse sludge, but disposal at sanitary landfills is acceptable if there are no alternatives. Although there exist a number of different sludge treatment technologies, in actual practice only four are used in Quebec: lagooning, dewatering, reuse for agricultural purposes and direct disposal in municipal sewerage systems. Composting also looks promising, and is currently being developed.

Lagooning is a type of anaerobic stabilization in which the inert settleable solids settle to the bottom. The sludge is poured into lagoons which are most often near a sanitary landfill. The liquid portion of the sludge seeps into the soil and is treated by the natural microflora. Although this management method is inexpensive, it can result in contamination of the water table. This practice is coming under increasing criticism and is not a viable long-term solution.

Dewatering using fixed or mobile equipment creates sludge that is "shovellable" and therefore fairly solid, which can be disposed of in a sanitary landfill. However, the filtrate (the liquid portion removed from the sludge) must either be treated on site or at a municipal sewage treatment plant.

The agricultural use of raw (non-dewatered) sludge is also an option, but it poses two problems: the cost of transporting small volumes of sludge, and the need to stabilize the sludge to destroy pathogens. Furthermore, since sludge can only be spread at certain times of the year, temporary storage facilities are required.

Direct discharge into municipal sewers can be done if the volume of sludge is small enough in relation to the capacity of the treatment facilities. However, sewage treatment plants are not designed to treat sewage containing high concentrations of suspended solids or a very high BOD, and this type of management is not recommended.

Land application of raw sludge is also not recommended because the organic matter is not sufficiently degraded to meet fertilization requirements. In addition, raw sludge contains pathogenic microorganisms, another factor that must be taken into account. Studies have shown that composting septic tank sludge is technically feasible. The compost produced is suitable for agricultural use in that it has the available minerals (mainly N and P), can be used as an organic soil amendment and the quantity of pathogens, mainly coliforms and *Salmonella*, is greatly reduced.

While there is no universal solution to the management of septic tank sludge, the current trend is to dewater sludge prior to its disposal. Dewatered sludge may be spread on the soil as a fertilizer, sent to a sanitary landfill or be put back in septic tanks to "seed" them with the microorganisms required to metabolize organic matter.

Regulations

Individual sewage treatment is covered mainly under the Quebec *Regulation Respecting Waste Water Disposal Systems for Isolated Dwellings* (Q-2, r. 8). These regulations, which are fairly comprehensive, set out the characteristics and specifications of various technologies used to treat domestic wastewater, including septic tanks and tile fields, sand filters, latrines and peat biofiltration. The capacity of the septic tank is determined on the basis of on the number of bedrooms in the residence. Tanks used year-round must be pumped out every two years. There are no specific requirements respecting sludge disposal, except that it must be done in accordance with section 22 of the *Environment Quality Act*, which stipulates that an authorization certificate is required to dispose of contaminants in the environment.

Public health risks not yet fully known

Efforts directed at the chemical and, especially, microbiological characterization of septic tank sludge must be pursued. Little information is available on the presence of some pollutants (such as surfactants and alkylbenzenes) and some groups of parasites. In addition, no epidemiological monitoring seems to have been done on people handling septic tank sludge on a daily basis. In this context, the public health risks can only be determined after better characterization of sludge has been carried out.

Sector: Septic tank sludge
Activity: Handling or land application of septic tank sludge

STRESSOR/ EXPOSURE	Nature of stressor	Impact on environment	Zone of influence	Control measures	Standards or recommendations
Technological disaster					
Gas or atmospheric emissions	- fungal or bacterial spores	- pollution, unhealthiness	- site	- careful handling, mixed into soil instead of on surface	- none
Liquid effluent or in water	-some heavy metals (mainly Fe, Al, Zn and Cu)	- toxic to some aquatic organisms	-receiving waters	- respect protective riparian strips	- Al < 0.1 mg/L to prevent Alzheimer's
	- biodegradable organic compounds (proteins, sugars, lipids)	-reduction of dissolved oxygen in water	- " "	- " "	- 3 - 7 mg/L (MEF criteria for untreated water to be chlorinated)
	- enteric bacteria and viruses	- unhealthiness	- " "	- " "	- fecal coli.: 0 total col.: 10/100 mL (Potable Water Reg. QC)
	- eggs and cysts of parasites (*Ascaris*, *Trichuris*, etc.)	- unhealthiness	- " "	- " "	- none
Solid emissions or in soil	- heavy metals	- soil pollution	- usually site only (not very mobile)	Do not spread too often at same site	- none
	- eggs and cysts of parasites, bacteria and virus spores	- unhealthiness	- usually site only (not very mobile)		- none
Nuisance	- odours	- unhealthiness	site and surroundings	buffer zone, inject sludge into ground	municipal bylaws
Indirect impacts or other exposure	handling sludge (micropathogens)	unhealthiness	site	protective equipment and clothing	

STRESSOR/ EXPOSURE	Health effects	Population at risk	Probability of occurrence	Biological and environmental indicators (monitoring)	Information/ references
Technological disaster					
Gas or atmospheric emissions	- allergies, resp. irritations	- unknown	- unknown	- cfu per m^3 for handling or application of sludge	Boulanger *et al.* (1988) Labelle (1995; 1996)
Liquid effluent or in water	- various toxic effects, risk of Alzheimer's because of aluminium	- people who drink polluted water	- unknown	For all pollutants, determine concentration in runoff from treated areas and in drinking well water epidemiological monitoring of local populations near areas treated frequently	Boulanger *et al* .(1988) Consultants RSA (1997) Marin and Roy (1996) Labelle (1995; 1996)
	- unhealthiness, formation of trihalomethane if water if to be chlorinated	- people who drink polluted water	- unknown		
	- mainly gastro-enteritis	- people who drink polluted water	- unknown		
	- direct parasitosis	-people who drink polluted water	- unknown		
Solid emissions or in soil	- see above	- people handling sludge	- unknown	Determine presence of most dangerous pollutants. Monitor workers if necessary	
	-see above	- " "	- unknown		
Nuisance	- quality of life	- neighbours and community	unknown	- complaints, perception studies	
Indirect impacts or other exposure	infections	workers	unknown	- epidemiological monitoring of local populations near treated areas	

References

Blanchard, J., M. Joseph and P. Purenne (1990) *Programme expérimental de réception et de traitement des boues de fosses septiques*. Environmental Department, Montreal Urban Community, 24 p.

Bossé, Y. (1990) *Gestion des boues d'épuration et de fosses septiques et effets potentiels de leur valorisation en milieu agricole. Commission de protection du territoire agricole du Québec*(Quebec agricultural land protection commission), 89 p.

Boulanger, D., J.-M. Jalbert and A. Terreault (1988) *Guide sur la gestion des boues de fosses septiques*. Department of the Environment (Government of Quebec), various pagings..

Caron, J.-J. and F. Poulin (1995) *Démonstration et optimisation du système DAB™ pour la déshydratation des boues de fosses septiques et municipales*. Prepared by Valoraction for the Quebec Department of the Environment and Wildlife, Government of Quebec, final report, 206 p. + appendices.

Consultants RSA (1996) *Développement d'un camion-usine servant à déshydrater les boues de fosses septiques sur place.* Prepared for Canmex Inc. and the Quebec Department of the Environment and Wildlife (Government of Quebec), summary report, 54 p. + appendices.

Côté, L. and D. Potvin (1994) *Essais de compostage de boues de fosses septiques*. Report to Fourth Annual Convention of Canadian Composting Board (Toronto), p. 359-389.

Labelle, A. (1995) *Utilisation des boues d'usines d'épuration et risques à la santé. BISE (Bulletin d'information en santé environnementale)*, 6(3):__ - __.

Labelle, A. (1996) *Valorisation des boues d'épuration municipales; quels sont les risques de contamination?* Direction de la santé publique Mauricie-Bois-Francs 46 p.

Lalumière, A. (1993) *La gestion des boues des stations d'épuration et des fosses septiques.* Proceedings of conference entitled *"La gestion de l'eau par les municipalités, à quel prix?", Union des municipalités du Québec*, 8 p + figures.

Marin, M. and R. Roy (1995) *Évaluation de l'accumulation des boues dans les fosses septiques au Québec*. Prepared by the Groupe Steica for the Department of the Environment and Wildlife, Government of Quebec, final report, 98 p. + appendices.

Construction and operation of a sewage disposal plant

Nature of project

This grid is based in part on an impact study on a sewage disposal plant for Halifax and Dartmouth, Nova Scotia, involving the primary treatment of raw wastewater, followed by chlorination, prior to disposal in Halifax Harbour. Solid residues recovered through tertiary treatment would be incinerated. Since the Halifax project is very specific, the following paragraphs include information relevant to other types of sewage disposal to give a larger scope to the grid.

General information on urban wastewater treatment

Each wastewater treatment plant is designed to suit the needs of a given region and can include multiple combinations of treatment processes. However, the basic concepts are almost always the same and are briefly described below.

In most cases, urban wastewater is treated using so-called conventional methods (pretreatment, primary treatment and secondary treatment); occasionally, tertiary treatments called special or complementary treatments are used. Pretreatment involves screening to remove coarse solids larger than 15-25 millimetres and grit removal to sediment particles between .2 and 25 millimetres in diameter. Pretreatment can also include oil and grease removal to remove water-insoluble liquids (oils, hydrocarbons, grease, etc.). Primary treatment, carried out essentially by decantation, eliminates about 70% of the small inorganic particles (0.05 mm to 1 mm) called suspended solids (SS) and 40% of the biochemical oxygen demand (BOD), which indicates the level of organic matter pollution.

Secondary treatment is a biological process that uses various indigenous microorganisms, mainly bacteria, to metabolize organic matter into microbial biomass, mineral elements (nitrogen, phosphorus, etc.) and CO_2. It removes non-settling organic matter that was not caught in the primary treatment and usually destroys pathogenic microorganisms (bacteria, viruses, fungi and zoomicrobes) The most commonly used processes are activated sludge and trickling filters. Biological treatment is increasingly considered indispensable since it is the only process capable of significantly reducing organic and microbial pollution.

Tertiary treatments are rarely used and are aimed at producing water that is almost pure, although not drinkable. They include physical processes like sand filtration (removal of particles and microorganisms), activated carbon (absorption of organic matter resistant to other treatment phases) and disinfection through the addition of ozone and through exposure to ultraviolet rays. Chemical processes include flocculants and coagulants to precipitate certain organic particles, phosphorus, which has a very high eutrophication capacity; and chlorine compounds for disinfection. Biological processes use bacteria to eliminate nitrogen (nitrification or denitrification) or phosphorus (phosphate removal).

Several types of treatment can be involved without necessarily following the usual sequence of primary, secondary and tertiary. The Halifax-Dartmouth project, for example, uses primary treatment followed by chlorination (tertiary chemical treatment).

Atmospheric waste

Machinery used during construction emits various pollutants, principally nitrogen oxides (NO_x), carbon dioxide (CO_2), carbon monoxide (CO) and volatile organic compounds (VOCs), which may also be emitted during the plant operation.

Carbon monoxide (CO) is an odorless gas that can cause potentially fatal carboxyhemoglobinemia, and carbon dioxide (CO_2) is one of the principal greenhouse effect gases.

Nitrogen oxides (NO_x) include nitric oxide (NO) and nitrogen dioxide (NO_2). NO_2 is a brownish gas with a sharp, irritating odour that can oxidize cell membranes. This gas can decrease odour perception, alter pulmonary function and in cases of severe exposure, can lead to pulmonary edema. One of the most significant effects of chronic exposure is emphysema and a reduction in forced expiratory volume. NO_2 reacts with VOCs to form photochemical smog (see below).

Volatile organic compounds (VOCs) are hydrocarbons that evaporate at ambient temperature and exist in the atmosphere in the form of vapour; they number in the thousands, and some are relatively toxic. The average concentration of VOCs in wastewater would be in the order of 10 to 50μg/L, with peaks of close to 200μg/L. Certain VOCs, like benzene and chloroform, are carcinogens.

The photochemical reaction between NO_x and VOCs produces secondary pollutants, collectively called photochemical smog. This smog contains ozone (O_3) at ground level (tropospheric), various free radicals and oxygenated hydrocarbons like aldehydes (e.g. formaldehyde) as well as peroxyacetyl nitrates (PAN). All these substances can be major respiratory irritants, and some are mutagenic (PAN) or carcinogenic (formaldehyde).

The incineration of sludge from primary treatment (Halifax project) or secondary treatment can produce the pollutants already mentioned (CO, CO_2, NO_x and VOC), as well as sulphur dioxide (SO_2), heavy metals (Pb, Hg, Cr or Cd), polycyclic aromatic hydrocarbons (PAH) and hydrogen chloride (HCl).

Incineration effluents usually contain gases, particles and fly ash, which are small, easily airborne particles that penetrate deep into the respiratory tract. Particles and fly ash contain diverse inert materials like silica and various volatilized metals.

Incompletely incinerated organic substances in the form of vapour can also condense on the particles. Volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and, above all, dioxins and furans have been identified in incineration effluents. According to the literature on the subject, the carcinogenic risk from incinerator dioxins and furans is fairly insignificant when the equipment includes various depollution systems.

Polycyclic aromatic hydrocarbons (PAHs) include a large group of compounds created through pyrolysis and organic matter carbonization. They are made up of benzene rings and include several carcinogenic compounds, the most well-known being benzo[a]pyrene (BaP). The PAHs are released into the atmosphere, but can contaminate lakes and waterways during precipitation (rain or snow), accumulating in sediments and contaminating bottom fish and crustaceans like lobster.

As a general rule, atmospheric pollutants released during the construction or operation phase are not considered human health hazards in view of their low concentrations, which are comparable to those found in major urban Canadian centres. However, the inhalation of small doses of certain compounds (such as nitrogen oxides) can lead to disease in the long term, and can add to other pollutants causing climatic changes, destroying the ozone layer and causing acid rain or urban smog. Smog is a concern because of the health problems it causes and because it is an urban atmospheric pollutant that is on the rise in Canada.

Waste in the aquatic environment

Water treatment plants improve the quality of liquid waste in receiver waters by reducing inorganic, organic and microbial pollution. This reduction, however, depends on the types of treatment used. Because secondary treatment is not used in the Halifax project, organic matter and microbial pollution are not reduced significantly, and water is disinfected with chlorine. This is a questionable process because of its weak performance when there is a significant concentration of particles that interfere with its action.

Pollution problems with treatment plants are generally limited to the waste zone (the location of the treated water line) and downstream, in the discharge plume.

Health risks are assessed according to water uses: recreational (swimming, water skiing, canoeing, etc.) and the consumption of water and filter-feeding organisms (shellfish) or other species (fish and crustaceans). In risk assessment, the type of treatment must be taken into account. Secondary treatment is far more effective than primary treatment for the removal of pathogenic microorganisms. The effectiveness of disinfection (ultraviolet rays, ozone and chlorination), is highly relative since the presence of various contaminants (SS, organic particles, agglomerated microorganisms) can make it almost entirely ineffective. In chlorination there is the added risk of carcinogenic trihalomethanes forming because of high concentrations of organic matter when there has been no secondary treatment.

Recreational water uses

The recreational health risk is primarily due to pathogenic microorganisms that create gastrointestinal problems . The greatest bacterial risk is the family of *Enterobacteriaceae* (gram-negative bacilli of enteric origin). The bacteria most often involved are: *Escherichia*, *Enterobacter*, *Proteus*, *Salmonella cholerasuis* (responsible for non-typhoid enteric infections), *Shigella* and *Yersinia*. Other bacteria include *Campylobacter jejuni*, which is now considered the most widespread bacterial enteric infection of dietary origin in North America, and *Enterococcus faecalis*, which is resistant to antibiotics. Many of these bacteria colonize naturally in healthy individuals, and are only a risk for those who are immunodeficient. These are often opportunistic infections whose risk of triggering illness among exposed swimmers would be around 0.02 to 0.3%. Some bacteria survive for a long time in the aquatic environment, notably *Enterococcus faecalis,* with a risk infection for swimmers of about 1 to 2% (or 10 to 100 times greater than the enterobacteria). The detection of this bacteria is a good estimate of the quality of swimming water, although the presence of coliforms remains the determinant used by official methods. These data are compiled from fresh water studies; the survival of microorganisms can be different in salt water.

Scientific documentation on viruses associated with wastewater disposal notes risks from two virus groups of the family of *Picornaviridae*, belonging more specifically to the genus *Enterovirus*: the Coxsackievirus and the echovirus, whose clinical manifestations include aseptic meningitis, conjunctivitis, pericarditis, diarrhea and encephalitides causing Reye and Guillain-Barré syndromes. Coxsackieviruses are responsible for a significant proportion of acute myocardites. The risk of the transmission of the poliomyelitis virus (*Picornaviridae*) via wastewater is a very slight probability. In the family of *Calciviridae*, the Norwalk virus often causes violent gastroenteritis that lasts from 24 to 48 hours among patients who drank non-potable water or practiced primary contact water activities. Urban wastewater can also cause *Hepadnaviridae* (hepatitis B) infections.

Giardia lamblia and *Cryptosporidium parvum* are the zoomicrobial parasites most commonly carried by wastewater. The cysts and oocysts of these organisms are extremely resistant to wastewater treatment processes, including chlorine disinfection, and have a high level of infectiousness (a handful of Giardia cysts can cause giardiasis). Cases of giardiasis and cryptosporidiosis of hydric origin are rising steadily in North America; giardiasis is now the most frequently occurring non-bacterial enteric infection.

Primary contact sports like swimming and water skiing in urban wastewater disposal zones are generally not permitted, even if the water has been treated. Secondary contact activities like canoeing should only be allowed after an adequate assessment of the presence of various pathogenic microorganisms including the detection of groups other than coliforms.

Consumption of water and filtering organisms (mollusks) or non-filtering organisms (crustaceans, fish)

Filter-feeding organisms like mollusks are highly susceptible to bacterial and viral contamination. The main pathogenic bacteria that can be found in mollusks are *Campylobacter jejuni*, *Salmonella cholerasuis* (non-typhoid species) and *Shigella* sp which can cause gastrointestinal infections. *C. jejuni* is very saline-sensitive and rarely found in marine zones. Contamination by the same viruses transmitted through recreational activities is also possible. As a general rule, mollusks in urban or polluted zones should not be eaten, and drinking water should undergo complete treatment.

Risks due to the consumption of drinking water and non-filtering aquatic organisms are measured by the bioaccumulation of various inorganic toxic substances like heavy metals (especially copper, cadmium and mercury) and of organic substances (especially polycyclic aromatic hydrocarbons - PAHs - and polychlorinated biphenyls - PCBs).

Copper is essential for the maintenance of physiological functions, but in excessively high concentrations it causes necrosis of the liver. This intoxication, however, is extremely rare. Mercury intoxication by ingestion is caused by absorption of its methyl form, methylmercury. Methylation is facilitated by microorganisms that can the inorganic mercury in wastewater. Methylmercury attacks the nervous system and creates irreversible effects; affecting visual and auditive functions and coordination. Cadmium is principally industrial in origin, and can persist up to 20 years in the human body after ingestion. Chronic exposure results in renal necrosis. Although it is potentially carcinogenic when inhaled, this is not a risk when ingested.

Polychlorinated biphenyls (PCBs) are organochlorines that bioaccumulate in the food chain. They have a great environmental stability because they are thermoresistant and can only be destroyed at temperatures approaching 1000 ° C. When burned at temperatures below 800 ° C, they can produce large amounts of dioxin and furan. Although they have been banned in Canada since 1980, they persist in the environment and contaminate almost all human and natural environments. Chronic exposure can lead to liver damage and congenital defects, and they have been found to be carcinogenic in laboratory animals.

The characteristics of PAHs were covered in the section on atmospheric emissions. As noted, PAHs result from the pyrolysis and carbonization of organic matter. In wastewater they are produced through cleaning or washing activities in certain industries (especially heavy industry like metallurgy). Public health risks are due to mutagenic, teratogenic and carcinogenic compounds like benzo[a]pyrene.

Obviously, this list is not exhaustive. Numerous domestic use pesticides, oils and greases (from machinery and from the illegal dumping of motor oil) and endocrine disruptors, whose potential effects have only begun to be assessed, can also be factors. Endocrine disruptors include several pesticides (especially insecticides and fungicides), organochlorinated compounds (including PCBs) and ethoxylated nonyl phenols, which belong to the chemical family of alkylphenols. Nonyl phenols are present in several consumer products like liquid laundry detergents and aerosol stain removers. They are thought to affect the male and female reproductive systems and in certain cases are considered carcinogenic, but the scientific community has not reached a consensus on these risks.

Trihalomethanes (THMs), several of which are carcinogens, are produced by the reaction of chlorine with various organic compounds. Chloroform is the principal THM, followed by other highly toxic compounds like halogenated furanon, bromoform and dibromoethane. THMs can cause bladder cancer; in Ontario, 14% to 16% of bladder cancer cases are attributed to drinking chlorinated water. THM formation is clearly facilitated by wastewater treatment using chlorination. THMs are diluted in the receiving waterway, but if a drinking water plant is located downstream, their concentration could rise. Since most THMs have chronic toxic properties in concentrations of 50 μg/L, all situations that could produce them must be monitored.

Heavy metals can contaminate humans through the consumption of drinking water, fish or crustaceans, and bioaccumulative organic substances (PCBs and PAHs) contaminate through the consumption of fish and crustaceans. The ingestion of water seems to be sufficient for contamination by trihalomethanes and endocrine disruptors. Impact studies do not demonstrate serious contamination by heavy metals and organic substances following conventional wastewater treatment . However, in view of the other sources of contamination, concentrations of these substances in treated wastewater does represent a further risk . Consumption of fish or crustaceans living in polluted waters should be restricted or regulated.

Solid wastes

Two principal groups of solid residue are produced by wastewater treatment: sludge and incinerator ash.

Wastewater sludge is generated mainly by primary and secondary treatment, and makes up the lion's share of solid residue. Liquid residue containing 92% to 95% water when leaving the settling tank undergoes several drying treatments. Prior to dehydration the sludge usually has to be stabilized to mineralize organic matter and destroy active pathogenic and non-pathogenic microorganisms. Stabilization also reduces odour; fresh sludge, especially after primary treatment, is extremely foul-smelling. Stabilized and dried sludge produces a humid sludge cake; further drying would be too expensive.

Sludge can be used as agricultural and forestry fertilizer, but this use is limited by the potential presence of numerous toxic substances, especially heavy metals and persistent organic compounds like organochlorinated pesticides, PCBs, phenols and hydrocarbons, as well as certain pathogenic microorganisms. Composting and spreading kills microorganisms but has no effect on toxic substances, although some evaporate through the heat of composting or drying or through the metabolic action of microorganisms. Sludge must be disposed of in sanitary landfills or isolated, disused quarries (sand pits and gravel pits) if it cannot be used as fertilizer.

Sludge or any other waste incineration produces flying ash containing combustion gases and volatile particles that contribute to atmospheric pollution (see above section), as well as non-volatile bottom ash. Bottom ash is very dense and contains noncombustible refuse, steel and vitrified, carbonized or crystallized organic matter. Its principal ingredients are heavy metals in the form of oxides and insoluble silicates, PAHs, chlorobenzenes and chlorophenols. The health risk varies according to the presence and concentration of these substances, but bottom ash is not generally considered toxic. However, it must be buried in special isolated landfill sites to avoid dust inhalation. Contamination of the water table must also be avoided by choosing landfill sites with impervious soil or using waterproof geomembranes and leach water collection systems.

Psychological and social impacts

Wastewater treatment plants generally have positive social impacts since they reduce water pollution, improving the appearance and quality of water courses for recreational use. A major wastewater treatment complex can, however, impact psychologically and socially on adjacent residents because of the odours generated by the treatment process and sludge disposal. This is why plants are usually built in less populated sectors; provision can also be made for a large buffer zone, usually a grassed or wooded area. If sludge is incinerated on site, the smoke must be neither too thick or foul-smelling. In most cases, psychological and social impacts are reduced quality of life and reduced property values.

Sector: Sewage Sludge Management
Activity: Construction and Operation of a Wastewater Treatment Station

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Zone of Influence	Control Measures	Standards or Recommendations[27]
Technological Disaster	fires and explosions	pollution from smoke, particulates	air and water: site and perimeter	confinement, containment, emergency measures	CSA Z731-05: emergency measures planning for the industry?
Gaseous or air emissions	- CO	- negligible	- site and perimeter	- combustion control	- 35 mg/m^3 (1h)
	- NO$_2$	- smog and tropospheric ozone	- local to regional	- catalytic reduction	- 200 µg/m^3 (24h)
	-dioxins, furans, PAH	- bioaccumulation in land and aquatic animals	- continental and global	- improved combustion	- 100-200 ng/m^3 for PAH, 30 pg/m^3 for dioxins and furans
	- heavy metals (Hg, Cr, Cd)	- contamination of animals	- regional and continental	-flue gas cleaning	- none for Hg, Cr or Cd
	- VOC	- smog and tropospheric ozone	- local to regional	- containment or ! combustion performances	- none
Liquid emissions or discharge into water	- heavy metals (Hg, Cr, Cd)	- toxic for certain aquatic organisms	For all pollutants: receiving waterways. Contamination distance varies according to concentration, solubility, temperature, pH, etc.	For all pollutants: use high-performance, adequate treatment techniques. At the least, secondary treatment to remove pathogenic micro-organisms. Resistant organic substances (PCB, PAH) may require tertiary treatment.	- Hg: 1 µg/L; Cr: 40 µg/L; Cd: 0.2 µg/L
	- PCB	- bioaccumulation in food chain			- 0.02-0.07 µg/kg.j (EPA standard)
	- trihalomethanes	-mutagenic and carcinogenic			- 100 µg/L
	- endocrine disruptors	- reproduction disturbance, fetal malformations			- none (except for compounds like pesticides)
	- suspended solids (SS)	- unsanitary and reduced visibility			- 0.5 mg/L (raw water, for drinking water)
	- enterobacteria and *Enterococcus* sp.	- unsanitary			- for micro-organisms, standards for coliforms only: 0 fecal coli and 10 total coli/100 mL
	- *Picornavididae* and hepatitis B	- unsanitary			
	- *Cryptosporidium* and *Giardia*	- unsanitary			
Solid emissions or discharge into soil	-sludge/ sedimentation	- unsanitary, toxicity	- site and perimeter	- confinement, burial or fertilization	- municipal or provincial regulations
	- fly ash	- unsanitary	- site and perimeter	- confinement or burial	- municipal or provincial regulations
Nuisances	- odours	- unsanitary	- site and perimeter	buffer zone	- municipal regulations

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[27] These are federal standards and guidelines. For air pollution, this is the maximum allowable concentration (MAC).

Indirect impacts or other exposures	-social conflict, property devaluation	- economic value	- perimeter and vicinity	-financial compensation, communication	- provincial and municipal regulations

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Environmental/ Biological Indicator (Monitoring)	Information/ References[2]
Technological Disaster	- trauma, injury, death	- workers, persons onsite	-very rare	- morbidity/mortality reports; fire service reports	
Gaseous or air emissions	- ↑ in % of carboxyhemoglobin, death	- drivers, persons in vicinity	- rare	- % of carboxyhemoglobin	Bio-Response System Ltd and Jacques Whitford Environment Ltd (1992)
	- irritation of respiratory tracts	- urban and near-urban zones	- rare to moderate in large cities	- measure in ambient air	
	- some compounds are carcinogenic	- none in particular	- rare or unknown	- measure in ambient air if possible, epidemiological studies	
	- some cancers; renal or hepatic toxicity	- workers and persons close to emission sources	- rare or unknown	- measure in ambient air, epidemiological studies	
	- irritation of respiratory tracts, smog provoking tissue inflammation	- urban and near-urban zones, workers exposed	- rare to moderate in major urban centres	- measure VOC and ground-level ozone in ambient air, epidemiological studies	
Liquid emissions or discharge into water	- some cancers, renal or hepatic toxicity	- consumers of fish or crustaceans	- unknown or rare	- measure in flesh of fish, crustaceans; epidemiological studies	Bio-Response System Ltd and Jacques Whitford Environment Ltd (1992)
	- potential carcinogenic effects	- primarily consumers of oily fish	- unknown or rare	- measure and epidemiological studies	
	- potential carcinogenic effects	- water consumers	- unknown or rare	- measure in flesh and epidemiological studies	
	- effects on reproduction, decreased sperm count?	- unknown	- unknown	-epidemiological studies	
	- unsanitary, no direct effect	- recreational use	- rare to frequent	- measure SS in recreational waters	
	- gastroenteritis, bacteremia, resistance to antibiotics	-recreational use	- rare to moderate, depending on place	- coliform, enterbacteria and *Enterococcus* measurement, medical reports	
	- encephalitis, meningitis, pericarditis and other diseases	- recreational use	- rare to moderate, depending on place	- epidemiological follow-up, public health reports	
	- gastroenteritis	- recreational use, drinking water	- rare to moderate, depending on place	- epidemiological follow-up, public health reports	
Solid emissions or discharge into soil	- possible toxic or carcinogenic effects, pathogenic microorganisms	- workers or sludge handlers	- rare or unknown	- medical follow-up	
	-possible toxicity	- workers, ash handlers	- rare or unknown	- medical follow-up	

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[28] Several of these references are drawn from other impact matrices presented in this document.

Nuisances	- quality of life	- vicinity	- rare to moderate	- complaints, perception	
Indirect impacts or other exposures	- role of municipal assessment, quality of life	- vicinity and community	- rare to frequent	- complaints, role of assessment, perception studies	

References

Altekruse, S.F., N.J. Stern, P.I. Fields and D.L. Swerdlow (1999). *Campylobacter jejuni*, an emerging foodborne pathogen. *Emerging Infectious Diseases*, 5: (Internet pagination) www.cdc.gov/ncidod/EID/vol5no1/altekruse.htm

Bio-Response System Ltd and Jacques Whitford Environment Ltd (1991) Draft Report to Halifax Harbor Cleanup inc. on Air Quality in the Environs of Halifax Harbour. 21p, + appendices.

Bio-Response System Ltd and Jacques Whitford Environment Ltd (1992) Final Report to Halifax Harbor Cleanup inc. on Human Health Risk Assessment. 43p. + appendices.

Bolduc. D.G., P. Maurice and M.-C. Messely (1992) L'enfouissement des cendres de l'incinérateur de la CUQ à Saint-Tite-des-Caps. Département de santé communautaire, Hôpital de l'Enfant-Jésus, Québec, 64p.

Chevalier, P. (1995) Gestion de l'environnement en milieux urbain et industriel. Presses de l'Université du Québec, 577p.

Chevalier, P. (1997) Technologies d'assainissement et prévention de la pollution. Presses de l'Université du Québec, 440p.

Crisp, T.M. *et al* (1998) Environmental endocrine disruption: an effects assessment and analysis. Environmental Health Perspective, 106 (suppl 1): 11-56.

Current, W.L. and L.S. Garcia (1991) *Cryptosporidiosis*. *Clinical Microbiological Reviews* , 4: 325-358.

Environment Canada, Health and Welfare Canada (1990) Canadian Environmental Protection Act. List of priority substances, substantiating document no. 1: polychlorinated dibenzodioxins and polychlorinated dibenzofurans. Environment and Health Departments, Government of Canada, 64p. *(translation)*

Environment Canada (1993) Canadian Environmental Protection Act. List of priority substances, substantiating document no. 3: pathways, ecotoxicities and regulations for PAHs in the environment. Department of the Environment, Government of Canada, 102p.*(translation)*

Gorbach, S.L., J.G. Bartlett and N.R. Blacklow (1998) Infectious Diseases, 2nd edition. W.B. Saunders Company, 2594p.

Gray, L.D. (1995) *Escherichia*, *Salmonella*, *Shigella* and *Yersinia*. In: Murray, P.R. (editor), *Handbook of Clinical Microbiology*, ASM Press, Washington, pp.: 450-455.

Hunter, P.R. (1997) Waterborne Diseases, Epidemiology and Ecology. John Wiley & Sons, England, 372p.

Levallois, P. (1997) Qualité de l'eau potable et trihalométhanes. Bulletin d'information en santé environnementale (BISE), 8(6): 1-4.

Mara, D.D. and D. Clapham (1997) Water-related carcinomas: environmental classification. Journal of Environmental Engineering, May: 415-422.

Parker, M.T. and L.H. Collier, editors (1990) Topley & Wilson's Principles of Bacteriology, Virology and Immunity. Edward Arnold, Volume 4, Virology, 719p.

Wolfe, M.S. (1992) Giardiasis. *Clinical Microbiology Reviews* , 5: 93-100.

See also texts and references used for the preparation of the following grids:

- Aluminum Production (for atmospheric pollutants);
- Roads and Highways (for atmospheric pollutants);
- Incineration (for atmospheric pollutants);
- Municipal Wastewater Treatment Plant Sludge Spreading (for water and soilborne pollutants);
- Domestic Septic Tank Sludge Handling or Spreading (for water and soilborne pollutants).

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

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Part 10 of 11

Manufacturing industries

Canadian perspective

Manufacturing is a significant component of Canada's economy. In 1993, some 39,000 manufacturing establishments generated 18% of the country's GDP (approximately $100 billion). However, since 1961, the manufacturing sector's share of Canada's GDP has been declining steadily, when it accounted for approximately 25% of the GDP. The same trend has been observed in the primary industries (metallurgy, pulp and paper, mining), whose share of the GDP dropped from 10% to 7% between 1961 and 1989. The manufacturing sector employs 1.8 million people, or 13% of the Canadian labour force. Its two largest components are transport equipment (15% of activities) and food processing (13%). Most of Canada's manufacturing activity, i.e., 70%, is concentrated in the Windsor-Quebec City corridor.

Reference

Canada (1996). The State of Canada's Environment - 1996. Government of Canada.

Aluminum production

Socio-economic profile

Aluminum production is a major industry in Quebec, with 90% of Canadian production centred in the province. Quebec is the world's third largest producer, behind only the U.S. and the former Soviet Union, with an annual production capacity of around 2.5 million tonnes. In 1993, the value of Quebec shipments totalled roughly $3.5 billion, providing direct jobs to 12,500 people. Quebec has several large smelters producing primary aluminum (obtained from bauxite; see below). Alcan is the largest of the Quebec firms, with four smelters in the Saguenay - Lac-St-Jean region (and a fifth in the works) and one in Shawinigan. Other major producers include Reynolds (Baie-Comeau), ABI (Bécancour), Lauralco (Deschambault) and Alouette (Sept-Iles). The aluminum sector industry is currently expanding, with several firms planning to modernize their facilities or construct new plants.

Description of aluminum production process

Primary aluminum is obtained from a raw material, bauxite (Bayer process), rather than from recycled aluminium (secondary aluminum). Since there are no bauxite deposits in Quebec, the raw material is obtained from places like Australia, Guinea, Jamaica and Brazil. Bauxite is composed mainly of aluminum hydroxides ($Al_2.H_2O$) and iron oxides, the latter giving it its characteristic reddish tint. Alumina (Al_2O_3) is obtained by dissolving bauxite in a concentrated, hot (250°C) basic solution (NaOH) under high pressure (autoclave principle). The production of 1.9 tonnes of alumina (which will ultimately yield one tonne of aluminum) requires 4 to 5 tonnes of bauxite. The residue, called red mud, is a fairly inert solid waste that is not considered hazardous. However, fugitive dust may escape from storage sites and be deposited on neighbouring communities. In Quebec, the only smelter that extracts alumina from bauxite is Alcan's Vaudreuil plant in Jonquière, which supplies alumina to Alcan's other facilities. The other Quebec firms import processed alumina from abroad, although some purchase their alumina from Alcan. In Jonquière, roughly 600,000 t of red mud is generated annually, which is thickened and piled, with a covering layer of gypsum, in various storage areas.

The alumina is transformed into aluminum using an electrolytic process, which occurs in the smelter's potroom. This process requires a large amount of electricity, each tonne of aluminum produced requiring between 13 and 17 million watts/hour of electricity (and a current between 60,000 and 300,000 amperes), which is why so many aluminum firms have established smelters in Quebec.

In the potroom, the alumina is placed in steel cells, or pots, along with various additives like cryolite (Na_2AlF_3) and aluminum fluoride (AlF_3) which reduce the fusion point to 950°C (instead of 2400°C). The electrical current passes from a carbon anode, a rod located in the centre of the cell, to the cathode, the carbon lining of the cell. At regular intervals, the melted aluminum produced is siphoned off and transferred to casting facilities.

Atmospheric pollutants

The transformation of alumina to aluminum is the most polluting stage of this process. It gives off numerous gases (called pot gases) and produces hazardous waste. If no additives were used and the reaction was complete, only CO_2, a greenhouse gas, would be produced. In practice, however, carbon monoxide and polycyclic aromatic hydrocarbons (PAHs) are generated, the latter coming mainly from the spent carbon anodes and pot linings. Old smelters using obsolete electrolytic processes (for example, the horizontal stud Soderberg process) produce significant quantities of PAHs, including carcinogens, such as benzo[a]pyrene (B[a]P). Studies show that the presence of PAHs in the ambient air may be associated with certain cases of bladder cancer in workers. Installing filters and making it mandatory for employees handling the pot covers to wear special safety equipment considerably reduces the risk of exposure.

The electrolytic process also produces dust, suspended particulates and sulphur dioxide (SO_2), which is present in the coke used to prepare the anodes. SO_2 is a major atmospheric pollutant contributing to the formation of acid rain and acid smog. This gas, which is almost completely absorbed between the nose and the pharynx, irritates the respiratory tract. Sulphur dioxide is also fairly damaging to plants, with concentrations around 0.03 ppm causing acute lesions on foliage.

Finally, we must mention the emission of gaseous fluorides resulting from fluorine additives used in the pots. Fluorine is an extremely toxic, very reactive gas that causes disintegration in almost all other elements except for oxygen and nitrogen. Aluminum smelters are the main source of atmospheric fluorides in Quebec. Plants are very sensitive to atmospheric fluorides and often are used as bioindicators. In mammals, absorbed fluorine is retained in dental and bone tissues, and may cause bone atrophy and dental fluorosis, the main symptom of the latter being an orange-brown pigmentation in the teeth. In the 1940s, some farm animals that grazed regularly in pastures around smelters were found to have these ailments.

Hazardous wastes

As previously mentioned, the internal lining of the cells is made of brick, composed mainly of anthracite and other refractory materials called pot wash, which constitutes the cathode. This lining ages over time and must be removed. Although the lining consists mainly of carbon, it is impregnated with cryolite and aluminum fluoride, as well as cyanide, which is a byproduct of electrolysis. The old pot linings are considered hazardous waste, not only because they contain toxic substances but also because, with contact with water, acids or alkalis, or at high temperatures, they may produce toxic or even explosive gases, such as hydrogen fluoride or hydrogen cyanide. Old pot linings are usually stored in a secure place until a way to reuse or decontaminate them can be found.

Water pollution

Many of these pollutants released into the atmosphere are also present in water, particularly fluorides and PAHs. Smelter effluent can also contain total suspended solids and oils and greases from machinery. This is more common in old smelters, with the more modern ones being models in terms of liquid effluent treatment. Changes in production processes and the presence

of treatment systems have resulted in effluents that are much reduced and relatively non-polluting. Some smelters even have zero effluent discharges, except for sanitary wastewater.

Some smelters have a sector called the carbon plant where the anodes suspended in the electrolytic cells are produced. Since these anodes become spent after time, they must be periodically replaced, usually every 20-30 days. Formerly, anodes were cooked in the pot, with the coke and pitch binder being transformed into graphite. Modern smelters produce prebaked anodes in their carbon plant. This production usually generates pollutants such as PAHs, which result from the heating of carbon compounds.

In conclusion, it must also be mentioned that secondary aluminum, made from recycled scrap, saves up to 95% of the energy used in making primary aluminum, and greatly reduces pollutants since electrolysis (the transformation of alumina into aluminum) is not needed.

Sector: Industrial Activity: Aluminum production[29]

STRESSOR/ EXPOSURE	Nature of stressor	Impact on environment	Zone of influence	Control measures	Standards or recommendations
Technological disasters	fires, explosions, spills, floods	toxic gases and liquids; destruction	site, surroundings and neighbourhood	Recovery, containment, interception	CSA Z731-95 Emergency Planning for Industry
Gas or atmospheric emissions	- fluorides	- dieback in plants and decalcification in mammals	- site, surroundings, neighbourhood	-scrubbers, new technologies, buffer zones	-2.5 $\mu g/m^3$ (24h), (workplace)
	- SO_2	- acute chronic lesions in plants	- regional (up to 100 km)	- scrubbers, non-sulphur fuel	- 0.5 ppm (1h) and 11 ppm (24h) (Q-2 Reg. atmos. quality)
	- CO_2	- greenhouse effect	- global	- reduce fossil fuel use	- none
	- PAH (anodes)	- none	- site and neighbourhood	- capture	- 0.2 $\mu g/m^3$ (8h) total PAHs (MUC[30])
Liquid effluent or in water	- aluminium	- toxic for fish and aquatic insects	For all pollutants: receptor watercourse	For all pollutants in water: abstraction and treatment	- 0.2 mg/L (MEF criteria untreated water intake -1.0 mg/kg/j (WHO)
	- fluorides	- bioaccumulation in aquatic organisms			- 1.5 mg/L (Reg. Potable water, MEF) 60μg/kg/d (EPA)
	- suspended and dissolved solids	- unhealthiness, reduced visibility			- 0.5 g/L (Environ. Canada criteria, untreated water)
	- oils and greases	- unhealthiness			- no criteria
	- PAH (from atmosphere)	- neoplastic and genotoxic effects			- 2.8×10^{-6} mg/L (MEF untreated water) 1/7.3 mg/kg/d (estimated risk, B[a]P, EPA)
Solid emissions or in soil	- used pot linings	- very toxic	- site	- safe confinement	- Q-2, Hazardous Waste Reg. - Q-2, Reg. solid waste
	- dross, grit	- unhealthiness	- site	- recovery, recycling	
	- domestic waste	- unhealthiness	- site	- disposal, recycling	
Nuisance	Noise (fixed and mobile sources)		site and surroundings	- noise abatement bank -buffer zone	L_{eq} 45dB (night)
Indirect impacts or other exposure					

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[29] Impacts evaluated in the current content, excluding old polluting technolgies (Soderberg process). The analysis includes the carbon plant, a sector not found in all smelters, but excludes the production of alumina from bauxite, which is usually done outside Quebec.

[30] Montreal Urban community air quality standard

STRESSOR/ EXPOSURE	Health effects	Population at risk	Probability of occurrence	Indicators, monitoring	Information/ references
Technological disasters	resp. irritation, asphyxia, injury, death	workers and immediate neighbours	very rare	morbidity/ mortality ratio MEF DATA BANKS???	
Gas or atmospheric emissions	- eye, skin irritations, dental fluorosis, osteoarthritis	- workers	-rare - very rare - N.A. - frequent - very rare	- fluorides in ambient air	- BAPE (1997) - ECB (1986) BAPE (1997) Reg. air quality (QC) - Jacques (1992) - Environment Canada (1994)
	- irritations of mucous membranes in respiratory tract	- none at concentrations emitted		- SO_2 in ambient air	
	- climate change	- global		- concentration of atmospheric CO_2	
	- cancer (mainly lung, bladder)	- workers and Neighbours		- concentration of B[a]P and other PAHs in ambient air	
Liquid effluent or in water	- neurological problems	- those consuming water from receptor watercourse	- unknown	- concentration of Al in water	BAPE (1997) Lalonde (1991) Env. Canada; Canadian Water Quality Guidelines and MEF; Water quality criteria - Environment Canada (1994)
	- probably none at concentrations found	- N.A.	- N.A.	- concentration of fluorides in water	
	- unhealthiness	- none	- N.A.	- visual or quantities of SS in water	
	- unhealthiness	- none	- N.A.	- visual or quantities of SS in water; quantities of oils/greases in water	
	- cancer	- those consuming water or aquatic organisms	- unknown	- concentration of PAHs in water and fauna	
Solid emissions or in soil	- extreme toxicity,	- workers	- rare to occasional	- accident reports from incidents	Alcan data sheet on used pot liners (# A0026)
	irritation of skin and respiratory tract	- workers	-???	-	
	-??? - unhealthiness	-	-	-	
Nuisance	sleep disturbances stress	neighbourhood	occasional	complaints/ perceptions	

Indirect impacts or other exposure					

References

Alcan (1994) Alcan brochure. Alcan Smelters and Chemicals Ltd., Montreal, 20 p.

AIAQ (1993) *L'industrie de l'aluminium*. The Aluminum Industry Association (of Quebec), Montreal, 12 p.

BAPE (1997) *Projet de construction d'une usine d'électrolyse à Alma, par Alcan Aluminium ltée*. Bureau d'audiences publiques sur l'environnement (Government of Quebec), Report No.120, 180 p.

Capano, M (1996) *Rapport environnement.* Alcan Smelters and Chemicals Ltd. Montreal, 15 p.

Chevalier, P. (1995) *Gestion de l'environnement en milieux urbain et industriel.* Presses de l'Université du Québec, 577 p.

Fabri-Forget, M (1993) *PAH Emissions into the Canadian Environment, Supporting Document No. 1 for the National Evaluation Report on PAHs*, Environment Canada, various pagings.

Jaques, A.P. (1992) *Canada's Greenhouse Gas Emissions: Estimates for 1990.* Department of the Environment, Government of Canada, 80 p.

Lalonde (1991) *L'aluminerie Laterrière et la protection du milieu aquatique: vers une intégration harmonieuse*. Sciences et techniques de l'eau, mai: 145-150.

MEF (1993) *Bilan de l'environnement au Québec.* Quebec Department of the Environment and Wildlife, Government of Quebec, Éditions Guérin (Montréal), 560 p.

Sala, J,-M. (1992) *Sécal; dix ans de progrès sur la voie du développement durable. Quatrième colloque de formation en santé environnementale*, October 1992 (Quebec), 8 p. + appendices (document updated in 1993)

UNEP (1986) Guidelines for environmental management of aluminium smelters. UNEP-Industry & Environment Guidelines Series, United Nations Environment Programme, 42 p.

Other sources

Fact sheets produced by Aluminum Industry Association of Quebec on aluminum in Quebec, aluminum 100 years later, production and processing of aluminum and recycling aluminum

Fact sheets and documents produced by Alcan on aluminum metallurgy, Alcan in Quebec, paper presented to the Ninth World Clean Air Congress (1991) and the Bayer process.

Website on aluminum production process and world production (in French):
www.sfc.fr/Vignes/Vig3_al.htm#Alumine

Pulp and paper production

Canadian perspective

In 1994, there were 668 mills producing pulp, paper or related products in Canada. This industry makes a major contribution to Canada's trade balance, with newsprint exports of $5.5 billion (53% of world newsprint sales) and pulp sales of $6.7 billion (34% of world sales) in the same year.

Quebec production

Pulp and paper production is a key component of Quebec's economy. In 1995, the value of industry shipments (from just over 60 mills) represented 11.6% of all manufacturing activity in the province[31]. Pulp and paper mills provided 21,200 direct jobs and an additional 10,600 jobs in related sectors.

Technology

As explained further on, there are two main technologies for making paper pulp. In Quebec, most pulp produced is mechanical pulp (66% in 1995, or 4.8 million tonnes), with the rest being chemical pulp. Most of the mechanical pulp produced is used to make newsprint. In 1995, Quebec accounted for 11.8% of world newsprint production and 42.5% of total Canadian production. Elsewhere in Canada, as in the United States, chemical pulp accounts for two-thirds of total pulp production, the opposite of the situation in Quebec. This is significant from an environmental and public health standpoint, since chemical pulp production results in more toxic substances and greater nuisance.

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[31] Manufacturing activity should not be confused with gross domestic product (GDP), which is used in the descriptions of other types of activities.

Paper, which was first made in its present form in China 2000 years ago, is basically a sheet of entangled fibres. Paper can be made with various raw materials such as cotton, but wood is used in almost all modern mills. The cellulose molecules in wood pulp provide the fibre to make the paper. The various different papermaking technologies all have the same purpose, i.e., to separate the desirable cellulose (or other) fibres from the undesirable components, such as lignin.

There are two main pulping technologies, the mechanical and chemical processes. The mechanical process (using a grindstone) is the oldest; it provides high yields and generates little waste, but weakens the fibre in the process of separating it from the lignin. To obtain a stronger fibre, variations to this basic process have been devised, including thermomechanical and chemithermomechanical methods. There are two main chemical processes: the bisulphite (or acid) process and the sulphate or Kraft (alkaline) process. In the bisulphite process, the wood fibres are treated by sulfonation using a sulphur dioxide and alkaline oxide solution; the Kraft process relies on a caustic solution of sodium hydroxide and sodium sulphide.

Pollutants inherent in chemical pulping processes

It is important to fully grasp the environmental consequences of chemical pulping processes. First, the use of sulphur-based reactants results in the emission of foul-smelling sulphur compounds. The foulest odours produced by the pulp and paper industry are usually from Kraft pulp mills. Secondly, both chemical processes produce a fairly dark pulp that has to be bleached. The bleach generally used in both processes is chlorine-based (chlorine gas, chlorine dioxide or hypochlorite), which reacts with the organic matter in the pulp to produce dioxins, chlorophenols and chlorinated resin acids, known collectively as adsorbable organic halides (AOX). In the mechanical process, a less aggressive product, such as hydrogen peroxide, is generally used.

Atmospheric pollutants

The main air pollution problems caused by the pulp and paper industry result from its use of mechanical processes, and the combustion equipment required to heat the fibre and pulp. The use of combustion equipment is common to both mechanical and chemical processes. Therefore, the industry is responsible for emissions of suspended particulates and pollutants specifically related to fossil fuel combustion: carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x). Pulp mill emissions contain very high levels of NO_x, which is responsible for the formation of acid rain and photochemical smog (an ozone-depleting gas). Pulp mills also emit large quantities of CO_2, a greenhouse gas. Mills using chemical pulping technology produce various sulphur oxides (SO_x), including SO_2, and a number of foul-smelling compounds, such as hydrogen sulphide (H_2S) and thiols. As we have seen, sulphur dioxide (SO_2) is a major atmospheric pollutant that contributes to the formation of acid rain precipitation and acid smog. This gas, which is almost completely absorbed between the nose and pharynx, is irritating to the respiratory tract. Sulphur dioxide is also fairly damaging to plants, with concentrations around 0.03 ppm causing acute lesions on foliage.

Pollutants in aquatic habitats

The nature of mill effluent depends on the type of process used, but most mills probably release the following pollutants:

- suspended solids (SS) such as fibre and bark;
- organic matter, which increases the biological oxygen demand (BOD);
- various inorganic compounds (mainly aluminium, manganese and zinc);
- hydrocarbons from machine lubricants;
- resin and fatty acids and phenolic compounds.

Mechanical pulping mills generate mainly resin acids, cellulose fibres and pulp screening residues, which are discharged with the effluent. The actual paper manufacturing process (from pulp) may result in the release of fungicides and additives used to make the various types of paper, particularly coatings (kaolin, wax, solvents, latex, resins) and adhesives (flour adhesive, fish glue, starch adhesive, etc.). If the pulp mill also uses recycled paper, the effluent will contain coatings and adhesives along with printing inks for newspapers, Xerox toners, and offset, typographic, flexographic and rotogravure inks. Coatings are used to improve the texture of the paper by giving it a more uniform, smoother, more glossy or glazed finish. The most commonly used products include kaolin (a type of clay), wax, solvents, latex and various resins. Some are natural products (kaolin), while others are completely synthetic. All coated papers are not recyclable; kaolin-treated paper is, while papers treated with plastic are not. Adhesives may be of animal (fish glue, casein) or plant origin (flour, starch) or be made from synthetic resin (such as polyvinyl acetate). Synthetic adhesives are difficult to remove because they are often insoluble in water and form spots on recycled paper. Ink for newsprint has a mineral oil base, while offset inks are made from varnish solubilized in vegetable oil (linseed or soy). Flexographic inks are usually made from fine particles of carbon encapsulated in a water-soluble polymer. The particles, which are very tiny, are difficult to eliminate during de-inking, resulting in a significant reduction in the whiteness of the pulp. Finally, toners for photocopy machines are almost impossible to eliminate.

Resin acids

These acids (mainly pimaric and dehydroabietic acids) along with fatty acids (mainly oleic, linoleic and linolenic) are present naturally in wood. Various studies have shown that concentrations of these acids in effluent frequently exceed the limit above which mortality occurs in aquatic organisms. Quebec paper mills have been shown to have average concentrations of 6.9 mg/L of resin acids in their effluent. This figure should be no greater than 0.25 mg/L (at a pH of 7.0), the limit set by the Quebec Department of the Environment and Wildlife. However, it must be determined whether the concentration applies to raw effluent; dilution in water results in a considerable reduction of concentrations. Nonetheless, acids can accumulate in sublethal concentrations in the tissues of fish, molluscs and crustaceans. Since some of the acids have been shown to be mutagenic, their presence is of additional concern. Finally, it should be noted that effluent from mechanical pulp mills generally contains more resin and fatty acids.

Phenolic compounds

Effluent released in aquatic environments also contains phenolic compounds, such as cresol, catechol, guaiacol and others. These compounds occur in higher concentrations in softwood (fir, spruce, pine). Although these substances have a certain degree of toxicity in themselves, the chlorinated forms are the main cause for concern; these forms are only present in effluent from mills that use a chlorine bleaching process.

Solid waste

Most of the solid waste from the pulp and paper industry consists of "mill residue", which comprises bark, wood residues, refuse (pulp, paper and cardboard), ash from combustion facilities and sludge from the treatment of process water and de-inking. In the late 1980s, the 60 or so Quebec pulp and paper mills generated over 1.6 million tonnes of waste, most of which was sludge from the treatment of effluent (39%), bark (31%) and wood residues called splints (8%). Furthermore, 50% of the solids in de-inking sludge consist of kaolin, a substance used for coating paper (see above). This inert substance does not prevent the sludge from being reused, but it would be better to recover the kaolin for reuse. The presence of resins and inks may lead to a certain degree of toxicity in the sludge.

Interest has focussed on the reuse of sludge from treatment systems. The sludge resulting from the primary treatment of mill process water (in settling tanks) contains mainly macroscopic substances and particles. The sludge resulting from secondary (biological) treatment usually contains a number of toxic substances such as heavy metals, phenols, and resin acids that were not digested by the microorganisms used. It is well known that most heavy metals are fairly toxic, including mercury, chromium, lead, and zinc. Cadmium, arsenic, nickel and hexavalent chromium are carcinogenic. De-inking sludge may also contain toxic substances, particularly glues, plastics and inks.

Most of the sludge is buried at special sites. In the early 1990s, there were roughly 30 sanitary landfills for pulp and paper mill effluent. A small percentage of the sludge (less than 20%) is used in mill boilers fuelled by wood residues and bark. There have been experiments in using sludge in agriculture and forestry; the sludge contains some plant nutrients and can also be used as an organic soil amendment. In agriculture, however, these advantages may be offset by the presence of heavy metals that may be absorbed by growing plants.

In conclusion, the use of filters, cleaners and effluent treatment systems and the development of processes for reusing the solid waste as biosolids will allow the pulp and paper industry to become much less polluting.

Sector: Industrial **Activity: Thermomechanical pulp production**[32]

STRESSOR/ EXPOSURE	Nature of stressors	Impact on environment	Zone of influence	Control measures	Standards or recommendations
Technological disasters	fire, explosion chemical spill	smoke destruction contamination	site and surroundings	interception, confinement, recovery	CSA Z731-95 Emergency Planning for Industry
Gas or atmospheric emissions	- Vapour plume	- reduced visibility	- site	- keep at distance from traffic	- none
	- CO_2	- greenhouse effect	- global	- reduce fossil fuel use	- none
	- No_x	- accompanies formation of ground-level ozone and photochemical smog	- local and regional	- interception and treatment, energy efficiency	- NO_2: 0.2 ppm (1 h) and 0.1 ppm (24 h) (Q-2, Reg. air quality)
	- particulates	- unhealthiness	- site and neighbourhood	- dust collector	- 150 μg/m^3 (24 h) Q-2, Reg. air qual.
Liquid effluent or in water	- suspended and dissolved solids	- unhealthiness, reduced visibility	For all pollutants: receiving waters	- settling, primary treatment	- 0.5 mg/L Env. Canada criteria, untreated water)
	- phenols	- toxicity (mainly salmonids)		- secondary treatment	- 2 μg/L (Q-2 Reg. potable water) 0.6 mg/kg/j (EPA)
	- resin acids	- very toxic		- secondary treatment	- none
	- organic materials	-reduction in dissolved oxygen in water		- secondary treatment	- 3-7 mg/L (MEF criteria, untreated water to be chlorinated)
Solid emissions or in soil	- bark, mill residue	- unhealthiness (floating debris, scum)	- site and surroundings	- recovery, reuse for energy production	Q-2, Reg.on pulp and paper section VI
	- organic and inorganic materials from sludge from primary treatment	- unhealthiness, soil pollution	- site or landfill offsite	- sanitary landfill	
Nuisance	Odours	unhealthiness	site, surroundings and neighbourhood	buffer zone interception and treatment	Q-2, section X
Indirect impacts or other exposure	drop in value	economic value	surroundings and neighbourhood	compensation communication	Q-2, section IV

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[32] The process selected was thermomechanical pulping using sodium hydrosulphite bleaching, whih is common in Quebec.

STRESSOR/ EXPOSURE	Health effects	Population at risk	Probability of occurrence	Biological and environmental indicators (monitoring)	Information/ references
Technological disasters	resp. irritation, injury, death	workers and neighbours	very rare	morbidity/mortality ratios	
Gas or atmospheric emissions	- none	- none	- N.A.	- N.A.	MEF (1993)
	- climate change	- global	- frequent	- atmospheric CO_2 concentrations	
	- altered respiratory function	- residents of urban and near-urban areas	- rare to occasional (mainly in summer)	- atmospheric NOx, concentrations, epidemiological surveys of pneumonopathy	
	- irritation to resp. tract	- neighbours (asthmatics)	- rare	- epidemiological monitoring, quantification	
Liquid effluent or in water	- unhealthiness	- users of water (swimming, canoeing, fishing)	- occasional to frequent	- visual appearance of watercourse and SS measurements	- MEF (1993) - Lavallée, Rouisse and Paradis (1992) - Envirobec (1992)
	- bad tasting water or aquatic organisms	- consumers of water from polluted watercourse	- unknown	- phenol measurements in drinking water	
	- unknown	- unknown	- unknown	- quantification of resin acids	
	- unhealthiness and possible formation of trihalomethanes in presence of chlorinated water	- consumers of chlorinated water from polluted area	- rare to occasional	- BOD + quantities of trihalomethanes in drinking water	
Solid emissions or in soil	- unhealthiness (debris on ground), risk of injuries	- workers and neighbours	- unknown	- complaints, visual appearance	Q-2, Reg. on pulp and paper (r.12 and r.12.1)
	- unhealthiness (presence of vermin, insects, birds)	-workers and neighbours of sanitary landfills	- unknown	- complaints, visual appearance, inspection of landfill sites	
Nuisance	quality of life	neighbours and communities down wind	rare to frequent	complaints, studies of perceptions	

Indirect impacts or other exposure	assessment role	neighbours and community	rare to occasional	assessment role, studies of perceptions	

References

AIFQ (1993) *L'industrie des pâtes et papiers du Québec*. Association des Industries Forestières du Québec, 12 p.

AIFQ *(1996) L'industrie des pâtes et papiers, coup d'œil 1995*. Association des Industries Forestières du Québec, pamphlet.

Canada (1996) The State of Canada's Forests, 1995-1996. Canadian Forest Service, Department of Natural Resources, Government of Canada 112 p.

Chevalier, P. (1995) *Gestion de l'environnement en milieux urbain et industriel*. Presses de l'Université du Québec, 577 p.

CPPA (1995) 1995 Annual Review. Canadian Pulp and Paper Association (Montreal), 20 p.

ENVIROBEC (1992) *Étude sur les normes d'effluents basées sur la technologies pour le secteur des pâtes et papiers; fabrication de pâte mécanique de meule*. Document prepared for the Department of the Environment and Wildlife, Government of Quebec, 38 p.

Environment Canada (1991) Effluents from Pulp Mills Using Bleaching. Priority Substances List Assessment Report No. 2, Environment Canada, Government of Canada, 68 p.

Lavallée, H.C., L. Rouisse and R. Paradis (1992) *Caractérisation des effluents des usines de pâtes et papiers du Québec localisées sur le fleuve*. Science et techniques de l'eau (November 1992): 501-510.

McCubbin, N. (1983) *The Basic Technology of the Pulp and Paper Industry and its Environmental Protection Practices*. Training Handbook EPS-6-EP-83-1, Environment Canada (Government of Canada), 224 p.

MEF (1993) *Bilan de l'environnement au Québec*. Quebec Department of the Environment and Wildlife), Government of Quebec, Éditions Guérin (Montreal), 560 p.

Parent, B (1996) *Ressources et industrie forestières; portrait statistique*, 1996 edition. Quebec Department of Natural Resources, 142 p.

Smook, G.A. (1989) *Manuel du technicien et de la technicienne en pâtes et papiers*. Collège de Trois-Rivières (Quebec), 465 p.

CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2

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DRAFT

DECEMBER 1999

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Part 11 of 11

APPENDIX II

COMPARISON OF SOCIAL, ECONOMIC AND ENVIRONMENTAL SUSTAINABILITY

(from Goodland and Daly, 1995)

COMPARISON OF SOCIAL, ECONOMIC, AND ENVIRONMENTAL SUSTAINABILITY

Social sustainability (SocSus)

Socio-cultural stability is the social scaffolding provided through networks of organizations that empower self-control and self-policing in the management of natural resources. Resources should be used in ways that increase equity and social justice, while reducing social disruptions. Human rights, education, employment, women's empowerment, transparency of decision-making, fiscal accountability, and participation seem to be integral to SocSus. SocSus emphasizes qualitative improvement of social organization patterns and community well-being over quantitative growth of physical assets. It also projects cradle-to-grave pricing to cover full costs, especially social costs, and can be achieved only by systematic community participation. Social cohesion, cultural identity, diversity, solidarity, sense of community, love, tolerance, compassion, humility, patience, forbearance, fraternity, fellowship, institutions, pluralism, commonly accepted standards of honesty, laws, discipline, etc., constitute the part of social capital that is least subject to rigorous measurement, but probably most important for SocSus. This "moral capital", as some have called it, requires maintenance and replenishment by shared values and equal rights, and by community, religious and cultural interactions. Without this care it will depreciate just as surely as will physical capital. Human capital investments in education, health and nutrition of individuals are now accepted as part of economic development, but social capital, as needed for social sustainability, is not yet adequately recognized.

Economic sustainability (EconSus)

Economic capital should be stable. The widely accepted definition of economic sustainability is "maintenance of capital ", or keeping capital intact, and has been used by accountants since the Middle Ages to enable merchant traders to know how much of their sales receipts they and their families could consume without reducing their ability to continue trading. Thus Hicks' (1946) definition of income – "the amount one can consume during a period and still be as well off at the end of the period " - can define economic sustainability, as it involves the consumption of interest rather than capital. We now need to extrapolate the definition of Hicksian income from its sole focus on human-made capital and its surrogate (money) to embrace the other three forms of capital (natural, social, and human). Economics has rarely been concerned with natural capital (e.g. intact forests, healthy air) because until relatively recently it had not been scarce. This new pattern of scarcity of natural capital arose because the scale of the human economic subsystem has now grown large relative to its supporting ecosystem. To the traditional economic criteria of allocation and efficiency must now be added a third, that of scale. This scale criterion would constrain throughput growth -- the flow of material and energy (natural capital) from environmental sources to sinks, via the human economic subsystem. Economics prefers to value things in money terms, and it is having major problems valuing natural capital, intangible, intergenerational, and especially common access resources, such as air, etc. In addition, environmental costs used to be "externalised", but are just starting to be internalised through sound environmental policies and valuation techniques. Because people and irreversibles are at stake, economics needs to use anticipation and the precautionary principle routinely, and should err on the side of caution in the face of uncertainty and risk.

Environmental sustainability (EnvSus)

Although environmental sustainability is needed by humans, and originated because of social concerns, EnvSus itself seeks to improve human welfare by protecting the sources of raw materials used for human needs, and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans.

Humanity must learn to live within the limitations of the biophysical environment. Natural capital should be maintained, both as a provider of inputs (sources), and as a sink for wastes (Serageldin, 1993a). This means holding the scale of the human economic subsystem to within biophysical limits of the overall ecosystem on which it depends.

On the sink side, this translates into holding waste emissions within the assimilative capacity of the environment without impairing it. On the source side, harvest rates of renewables must be kept within regeneration rates.

Nonrenewables cannot be made fully sustainable, but quasi-EnvSus can be approached for nonrenewables by holding their depletion rates equal to the rate at which renewable substitutes can be created (see El Serafy 1991, 1993).

APPENDIX III

CLASSIFYING THE VARIOUS CATEGORIES OF RISK COMPARISON

(Covello, et al., 1988)

CLASSIFICATION OF RISK COMPARISON CATEGORIES [TRANSLATION]

1. **First class risk comparisons**
    1. Comparing the same risks on two different occasions.
    2. Comparing risks against existing standards.
    3. Comparing different estimates of the same risks.

2. **Second class risk comparisons (second option, less acceptable)**
    4. Comparing risks that are inherent to an activity with the risks occurring in the absence of such activity.
    5. Comparing the risks associated with different solutions applied to the same problem.
    6. Comparing the same risks as they occur in other sites.

3. **Third class risk comparisons (third option, less acceptable than the previous two)**
    7. Comparing average risks with the most serious risks encountered at a specific time or at a specific site.
    8. Comparing risks generated by a source producing a specific hazardous effect with the risks generated by all sources producing the same effect.

4. **Fourth class risk comparisons (fourth option, rarely acceptable)**
    9. Comparing risks with costs or comparing the risk/cost ratio with other risk/cost ratios.
    10. Comparing risks and benefits.
    11. Comparing professional risks and environmental risks.
    12. Comparing a risk with other risks generated by the same source, installation or agent.
    13. Comparing a risk with other causes linked to the same illness or trauma.

5. **Fifth class risk comparisons (last option, rarely acceptable, use with the greatest caution!)**
    14. Comparing a risk with other risks which are completely unrelated.

Method of categorizing and classifying risk comparisons by Covello et al., Risk Communication, Risk Statistics and Risk Comparisons, a Handbook for Plant Managers, Chemical Manufacturers Association, Washington, DC, 1988.